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CONFERENCE ON 'MAN VERSUS ENVIRONMENT'
MAY 5-6, 1958

Harry A. Faber, et al

California Institute of Technology

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May 5-6, 1958

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January 1959

CONFERENCE ON "MAN VERSUS ENVIRONMENT"

FOREWORD

The "Man Versus Environment" Conference was sponsored by the National Institutes of Health and Bureau of State Services of the U. S. Public Health Service.

The concept of a conference to delineate new and complex problems in the field of environmental health was proposed by Dr. Henry F. Vaughan, Chairman of the Sanitary Engineering and Occupational Health Study Section of the National Institutes of Health.

It was intended that the conference should emphasize the need for greater concentration upon research, planning, programming, and evaluation in order to control these problems.

There was agreement that a genuine need exists to evaluate such problems, and that a conference would serve a useful purpose in crystallizing the need.

In planning the conference, Dr. Vaughan was assisted by the entire membership of the Study Section and, particularly by Dr. Allen Brandt, Dr. Robert Kehoe, and Dr. Jack McKee.

The Public Health Service provided guidance through representatives of the following: Office of the Surgeon General, National Institutes of Health, Bureau of State Services, Division of Sanitary Engineering Services, and Division of Special Health Services.

Staff assistance in conference arrangements was provided by Mr. Irving Gerring (National Institutes of Health), Dr. Wilton J. Fisher (Division of Special Health Services), and Mr. Harry Faber (Division of Sanitary Engineering Services).

CONFERENCE ON "MAN VERSUS ENVIRONMENT"

PREFACE

Man's relation to his environment is changing precipitately, especially in terms of the complex problems of public health resulting from new developments in science and technology. The Conference on "Man Versus Environment" is designed to focus attention on the status of these problems in the major fields of water supply, water pollution, air pollution, food technology, and occupational health. It is the purpose of the Conference to evaluate the inter-relationships of new developments, to survey the status of research and training needs, and to determine areas in which activities should be initiated or expanded.

CONFERENCE ON "MAN VERSUS ENVIRONMENT"

PROCEEDINGS

Edited by

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INTRODUCTORY STATEMENT

MAN VERSUS ENVIRONMENT

by

Henry F. Vaughan

Much has been said of late about the changing vistas in public health practice. Throughout the country, both by scientific meetings of professional associations and by the lay press, emphasis has been placed upon three items: (1) the relative diminution in the incidence of the communicable diseases, (2) the marked increase in morbidity and mortality attributed to the chronic diseases, and (3) the disabilities of an ageing population. Less has been said about the changing problems and characteristics in the environmental health program.

Man has long struggled with the environment in which he has chosen to abide, and with the inter-relationships between himself and his fellow man.

Gordon in a recent discussion of "Man as an Organism" offers the pertinent statement that "The chief feature which distinguishes man from other animals is an ability to reason, and through his intelligence determine what he does to himself and to his environment. An unusual flexibility in adaptation also contributes, although in public health it seems to take three kinds of workers for reasonable accomplishment: the physician to adapt man to his environment, the engineer to adapt the environment to man, and the social scientist to adapt men to each other".

I am sure that Gordon may well have added the concept that no one of these three kinds of workers can function effectively in self-isolation. It requires teamwork, since there is no distinguishing dividing line between the responsibilities and the interplay of each. It is the purpose of this conference to provide a forum through which there may be a pooling of viewpoints, focusing upon our desire to serve those who are most concerned with scientific advances in the environmental health field.

From our viewpoint there is need for greater concentration upon research in the area of Sanitary Engineering and Occupational Health, and this can be promoted and accomplished through a realistic cooperation between healthmen, industry, and the public. The viewpoint of each is well represented in this Conference. We may do our share through this discussional in placing the solution of environmental health problems in a dynamic position compatible with the national economy and growing population.

Man's struggle for survival dictated early attention to his inanimate surroundings. The first promising advances in the control of disease pertained largely to the field of sanitation and cleanliness. The application of the recognized principles of sanitary science provided a noteworthy contribution to an improvement in water supplies, waste disposal, and the elimination of conditions and practices which were offensive to smell and frequently inimical to health.

Progress Brings New Problems

We find ourselves, however, in an ever-changing situation. The new products of industry, the movement of population, an expanding economy, a changing geography involving new atmospheric contacts, together with social changes, are factors which dictate the conditions under which man lives. Each of these factors and many others have a direct bearing upon our way of life. Some are old problems with new facets. Besides this there is a growing quota of problems, including those of radiobiology and the use of atomic energy, which remain largely unexplored and where the impact upon health and the survival of man remains to be determined.

Man has always employed water and air as a means through which to secure his wants and in part to dispose of his own accumulated wastes. The struggle for the use of these natural resources is becoming intensive. The demands for water come as a drinking resource; as a raw material in industrial processing; as an avenue of waste disposal, both from municipalities and industry; as a commercial fishery resource; as a source of recreation and the promotion of wildlife; as a water power resource and to meet the necessities of agriculture. Thus man's struggle is flavored by the natural elements of nature, such as flood and drought.

New adventures in industry, such as the increasing employment of synthetic chemicals, development and utilization of petrochemicals and the accelerated development of local nuclear energy sources, all keep the picture of the problems of water resources and waste disposal in a state of flux.

Changes are taking place which are entirely beyond the control of the traditional healthman. They are stimulated by the newer knowledge emanating from the centers of learning and from educational and industrial research, and production. It is within this framework that we welcome your discussions, with the expectation that they will be provocative in guiding toward new studies in Sanitary Engineering and Occupational Health which are broadly conceived and not limited to the provincial viewpoints of the Study Section members who gather periodically to examine the applications for research grants. We wish participation from all who are sincerely concerned with the trends in an ever-changing way of life which have their impact upon man and his environment and the relationship between men.

Many specific examples of the problems dealing with air pollution, foods, occupations, and other areas which have a definite bearing upon the survival of man in his chosen environment, could be cited. But the enlargement of this discussion, as to what should and what can be done will be left in abler hands. With this in view, the Study Section has chosen Dr. Kehoe to enlarge upon the theme. He will be followed by a group of nine speakers chosen because of their special interest in each of the five subjects which are a part of this conference.

* * *

KEYNOTE ADDRESS

HUMAN HEALTH AND THE MODERN ENVIRONMENT

By

Robert A. Kehoe, M.D.

Introduction

This conference is to concern itself with the threats to the health and well-being of man that lurk in his present environment and, specifically, in environmental conditions which, in some important sense, are peculiar to or characteristic of this period in the life of this nation. This is not to say that we have no concern for the larger society of mankind, or that various aspects of these discussions will not impinge upon a much wider segment of human life and experience than that represented in the United States of America. The attempt, however, is to come to grips with certain practical problems that have arisen among us, and to consider the steps which should be taken by those who bear professional or official responsibility for the health and safety of our people now and in the immediate future.

Clearly the health of a nation or a society involves much more than understanding and control of environmental factors of physical and chemical types, and there is some reason at this time for suspecting that the mental and emotional stress of our time may be its most significant feature in relation to the national health. Certainly the national and international climate, with its alarms and excursions, its uncertainties, and its potentialities for imposing sudden and perhaps disastrous social, political and economic

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consequences upon large segments of our population, is not conducive to ease of mind. Anxiety, apprehension and insecurity are exhibited all around us constantly, not so strikingly, to be sure, as the strident voices of the press and the radio would seen to indicate, but to such an extent, nevertheless, as to be readily apparent. Perhaps the ultimate response to this may be the toughening of our mental and moral fibre. If so, the signs which point to the opposite response are sporadic rather than general, and are to be fleeting rather than abiding.

Be these imponderables as they may, and be our methods of dealing with them as uncertain for some time to come as they now are and have been in the past, there are tasks before us which are within our understanding and competence, tangible threats to human life itself that we can counter, existing information which can and should be applied without further delay, and further knowledge to be gained by methods of investigation that are now available. The situation calls for prompt action for the avoidance of serious and widespread consequences. There is a great need, also, for more sensitive and more effective methods and tools for research, but this is no reason for not employing those we have, thereby developing facts and skills that will open up new avenues and methods of approach.

It is not necessary to study vital statistics in order to perceive some of the more glaring hazards of modern urban, or for that matter, rural, life. The severity of these hazards cannot be viewed in their proper proportions without quantitative information, but many departures from an earlier way of life have occurred within one or two generations, and thus the vital statistics of an earlier time, as well as the mechanisms for their collection, are hopelessly inadequate and even archaic. We are aware, however, of a heavy toll of deaths and injuries sustained on the highways and in the homes of the land; of accidental poisonings, especially among children, so numerous as to require regional and local poison centers for the prompt transmission of information and advice; of public apprehension concerning the role of air-borne carcinogenic agents, whether from the partial combustion of petroleum or tobacco, in inducing or contributing to the induction of lung cancer; of heated controversies over the treatment of community water supplies, and the contamination of food stuffs with insecticides and other foreign substances. And, in a fearsome awe, akin to that imposed by the unknown and unknowable, we contemplate with great uneasiness the dispersion in the air, and the deposition on the land and in the sea, of increasing quantities of radioactive substances. These are the things which are on the horizon of the average citizen.

Looking deeper into the situation with professional eyes, certain other features of the modern environment appear to have graver significance, in terms of present and future capacities for harm. Let us sketch two of these in fairly broad strokes.

Occupational Health In An Industrial Society

Through the centuries, man has been called upon frequently to risk his health and even his life, in wresting a living from the land, the sea, the workshop and the mine. But there has never been a time like the present in the history of nations or of men, generally, when man at work has been surrounded by such a multitude of obvious, as well as insidious, dangers to health, limb, organic integrity, and to life itself. Certainly there is a more general and humane concern - a greater fellow feeling - more indeed than ever before, for the health and contentment, as well as the economic status of the laborer. The laborer is also of a very different type than any seen in earlier times. His way of life, in very many respects, differs strikingly from that of previous earners of wages and salaries. Those of our day, especially in our nation, make up the majority of our population. Most of us work for a living, and whether we work with back and arm, or with the observing eye and the trained mind, whether with transport vehicles, earth movers, machine tools, instruments of precision, apparatus for communicating the spoken or written word, or equipment for making calculations at lightning speed, we carry on daily in the midst of a complexity of motion, sound, light effects, equipment, chemicals, and radiant and other forms of energy, that beggars description, and challenges physiological analysis.

Out of this welter of activities come physical and mental wear and tear, physical injuries to sense organs, limbs, and integument, and the organic structures of the body as a whole. Death occurs quickly through overt accident, but almost certainly it overtakes many men gradually, reducing their functional efficiency and shortening their lives. Occupational disease kills or disables, at least temporarily, and also takes its toll of life's productive years. By the study of the accidents and illnesses, we learn the cause of injury, disease and death.

But what are the consequences, through the working life time, of the frequent, almost daily, impacts of individual and collective insults of minor or sub-clinical severity? Those with more complacency than curiosity, with more faith in physiological adaptability than can be justified by medical evidence, and with undue comfort derived from crude statistics, will respond to this question with the statement that the people in no previous society have been known to die young in such small numbers, and to live to be old in such large numbers. The easy conclusion from these data is that Americans are healthier now than ever before, and that there can be no very serious threat to health in modern life. But let us look at the facts more thoughtfully and less superficially before we accept this conclusion.

We have reached, if not passed, the zenith of one of the most remarkable and brilliant periods of medical and hygienic history, during which our understanding of infectious diseases was advanced and applied at such a rate that many of the greatest scourges of mankind, in the form of endemic and epidemic diseases, have been almost utterly vanquished. This, the microbiological era of medicine and public health, as it might be called, has wrought a profound change in the practice of medicine, has brought into existence and has cultivated the techniques of preventive medicine, sanitary engineering, and public health, and has made revolutionary changes in the statistics of human morbidity and mortality. The diseases in this category have occupied the time and attention of the medical practitioner, investigator and educator, alike, for more than half a century, almost to the exclusion of others. Only in recent years, under the compulsion of the changed frequencies of the causes of illness and death, has attention begun to shift, proportionately, to chronic degenerative diseases and those of the aging segment of our population.

Meanwhile, the environment of the living, working population of the country has been changing, and the appreciably subdued microbiological threats to human life and health have been replaced by the inanimate threat of the machines and materials which inventive man has made, and by the forms of energy with which he has surrounded himself. The physical basis of modern industry is something new under the sun - an environment made by man which, in the making, has taken so much of his total time, effort, thought and ingenuity as to leave very little for expenditure on learning what might be its ultimate effects upon himself.

As might be expected, the most strategic site for the examination of the industrial environment and of its impact upon man, is within industry itself. Until recently, however, the medical and sanitary sciences have been represented but scantily among the personnel and facilities of industry, and the great proportion of American industrial organizations, especially the preponderant, small units, have operated almost entirely without benefit of preventive medicine and industrial hygiene. Moreover, medical and hygienic research have explored only the surface of the industrial environment; educators in medicine and sanitation have failed, for the most part, to recognize, much less to keep pace with, its existing hygienic problems. While we wait to muster our forces, and to deploy them in greater numbers and in a more effective manner, these problems grow in number and variety.

Only a minute proportion of our industrial organizations have valid medical information concerning the hygienic status of their employees, while the composite picture of the state of health of our general industrial population does not exist even in rough outline. Not only is the incidence of occupational disease unknown, because of the lack of suitable mechanisms for reporting and assembling information that comes to light, but great areas of industry are not under such observation as would provide such information. It is by no means certain, therefore, that the harmful effects of the composite hazards of industry have not exerted important and widespread effects upon the national health, which, because of the brilliant results of our efforts in the field of microbiological prophylaxis and therapy, may have been masked in our gross statistics of morbidity and mortality.

These comments are not made to incite apprehension, or to point the finger of accusation at any commercial, political or professional group, for indeed it is not likely that the national health has suffered disastrously or irreversibly up to the present time, and if it has been affected significantly, we are all at fault for our lack of vision and our preoccupation. Their point, however, is that we do not know, and we have no present means of knowing, just what has resulted from the profound changes wrought in the industrial environment by modern technology. As these changes progress in their complexity, how are we to know where they are taking us, hygienically speaking, unless we examine them closely, develop methods for their qualitative and quantitative appraisal, and equip ourselves to understand and control their effects? We are, indeed, becoming concerned about ionizating radiation, which has been far better studied and controlled, thus far, than almost any other newly exploited technologic development. Why are we not more deeply concerned about what has been happening to us, largely unobserved and with little anticipatory investigation, during the last half century, within which the environment of the day's work has been revolutionized?

We have been devoting large expenditures, magnificent facilities and the best brains of the country, in increasing numbers and proportions, to the development of new technologic departures from our previous handiwork. Why can we not devote an adequate proportion of the financial and intellectual resources of the country to the guidance of modern industrial technology in the ways of human safety and health? The time has come when we must carry out physiologic and hygienic research hand in hand with technologic research, and when we must develop the methods and techniques of industrial hygiene stepwise with the technology of production. True, this is being done, but only in token. Neither industrial management nor its hygienic advisors can be credited, generally, with a sound grasp of the situation or with plans for handling it.

Public Health In An Industrial Society

If we are concerned about our industrial population, we have cause also for concern about our population generally, for the industrial environment has become, to a remarkable extent, the national environment. We have called attention, to this, elsewhere, in commenting on the extent to which the problems of modern medical practice have their origin in industry. The "streets, highways, railways and airways (of the country) are hazardous because of the machinery and speed of transportation, and the great variety of the products transported; its homes and farms are dangerous because of many of the same factors that create industrial hazards - the number and variety of machines, the sources of power, the fuels and refrigerants, the drugs and chemicals that serve agriculture and the modern household; its streams, which are often its general water supplies, are polluted with common sewage, but also with all of the non-volatile substances that comprise the raw, intermediate and finished (chemical) products of industry; its food contains a host of natural substances of which the earth is composed, and variable quantities, as well, of scores of additives, contaminants and chemical substances derived from the modern use of fertilizers and insecticides, or from the multiplicity of materials employed in processing and packaging our foods; the air of its towns and cities, and often that of its open country side, is burdened with the smoke of dwellings and other buildings, of transportation equipment and of factories, and also with some portion of almost all of modern materials and chemicals, as these are released from the vents and stacks of industry. This new and dangerous environment, which man has created for himself, now provides the challenge to both curative and preventive medicine - a challenge that requires additional types of medical knowledge, new medical skills, and new settings for the application of such knowledge and skill." Let us examine more closely but one feature of this situation, with the idea of indicating some of the methods of investigation that will find application within the general field.

Some hundreds of new chemicals find new uses in American industry annually. These may be new plastics, plasticizers, or additives to alloys, fuels or foods; they may be pesticides, preservatives, solvents, detergents, adhesives or abrasives; or they may be part of the composition of fabrics used for clothing, household draperies and kitchen equipment. Many of these materials come into intimate contact with the people of the nation in their places of work, in their conveyances to and from work, and in their homes. Many of them enter directly into the food of the land, and many others find their way indirectly into the food, the water supply and the atmosphere. In these and other ways the chemicals find their way into the midst of the already complicated chemical reaction mass of the living human body.

In speaking of the chemistry of life, one is aware of certain complexities which have been revealed only partially and superficially by biochemical and physiological research. Man is composed in some part of the elements and substances that enter into the composition of the earth. The contributions made by certain mineral elements alone to the mechanisms of life have been investigated at length, but our general knowledge is but fragmentary and often fortuitous. Nevertheless, we endure our ignorance with a certain philosophical equanimity in recognition of the fact that the composition of the earth and the composition of man exist in an intimate historical and biological relationship which is inevitable and not of our making. But what can one think of the artificial situation, in which many new materials, possessed of many, almost an infinity of, possibilities for metabolic modification within the body of man, find their way into it, for better or worse. We shall never be able to anticipate and visualize the harmful potentialities of new materials until we achieve a comprehensive understanding of the role of the normal elements and other components of the living organism. Only on such a comprehensive background can we discover, fairly promptly, the metabolic deviations, if any, induced by new chemicals.

This brings us to consider the foregoing problem from a somewhat different viewpoint. No principle of biology is clearer than that which relates a physiologic response to a quantity of stimulus within appropriate limits of time. The living organism is resistant in varying degree, to varying stimuli, and the stimulus must be adequate to induce a response. It is this principle on which we base the differentiation of harmful versus harmless stimuli in terms of dosage and time. Toxicity, in these terms, does not relate to a specific substance but to a concentration of that substance arrived at within certain limits of time in the effective tissue or chemical system within an organism. A toxic environment, by the same token, is one which, again within certain limits of time, introduces into the organism a harmful quantity of a substance. The means by which this is done may be single or multiple - that is the medium may be the atmosphere, water or food, or any combination of these. The multiple environmental sources of human exposure to chemicals provide a good illustration of the complexities of the problem of public safety. Let us look at such a situation as it relates to a mineral constituent of the earth.

A mineral taken from the earth and brought into commercial use, may pose certain problems of industrial health, from the aspect of the toxicity of one or more of its ingredients. Measures of control can be provided on the basis of certain toxicologic facts, and certain products can be made available in the desired form or forms of commerce, without undue industrial hazard. In the process, constituents of the mineral have been discharged into the air around the production factory. These settle out on the land, thereby increasing its content of the mineral in question. Vegetation which grows out of such soil may take up the mineral from the soil, and the mineral may also be deposited upon the vegetation, which then, if eaten by animals or men, carries more than its natural content of such minerals into their bodies. Such domestic animals and animal products, used as human food, contribute to the total intake of the mineral by man.

At the same time, water-borne waste from the factory is conveyed away in pipes or ditches. This pollutes a stream nearby and affects an entire drainage area to an extent which may be only theoretical on the one hand, or highly significant on the other.

This process, in one form or another, may be multiplied in many or all parts of a country, so that a mineral constituent, brought forth out of the earth, comes to be spread far and wide in the air, in the water and in the food materials of animals and men over a continent, or even over the world. This same process, multiplied still further by the industry, agriculture and the other activities of a country, may so change the balance of nature, with respect to the numbers of the normal constituents of the earth and their proportional representation in the soil, water and atmosphere of the country, as to alter the mineral metabolism of mankind in the area concerned.

The illustration which we have chosen is only one of many that could be taken to follow the course of technologic man in his efforts to make use of the materials of the earth for his own purposes, to wrest from nature secrets that will feed, clothe and house her growing population, that will transport them with ever increasing speed to the four corners of the earth and beyond, and release energy from natural sources and direct it to carry out his bidding. In doing these many things, as has been pointed out elsewhere is great detail, man has changed and is changing further the face of the earth, has altered and is further disturbing the conditions under which life on this planet came into existence and has persisted, with changes and differentiation, for some millions of years. It seems likely that man's activities in strictly modern times, as represented in his technologic applications of the natural sciences, have brought about greater environmental changes of more profound physiological significance than have all the generations of men heretofore. During the greater part of historical times man has been contending with natural forces and natural threats to his survival. He has now moved into a period in which his knowledge and power have enabled him to modify the very conditions of his life. The time has come, however, when a much greater and more comprehensive knowledge of the consequences of our changed and changing environment must be had for our safety - perhaps for our very survival.

The efforts made to obtain the necessities of life and then to seek comfort, wealth and power have occupied most of the men of our time and every other time. The men of all ages, who have sought by the methods of their time to cultivate and protect the health of the people, have been few and their resources relatively small. The technology of our time has created a wealth of materials and made available the forces of nature for man's use. At the same time it has failed to bring to these materials and forces the understanding of their biological effects that will keep them under adequate control. The effort must be made to reduce the gap between technology and biology before it is too late. This will take time, studious effort and money: time for the training of experts in the various fields of medicine, hygiene and sanitation; studious effort to ferret out the problems most in need of investigation; money to initiate and catalyse the investigations without which we shall remain in relative ignorance.

It must become an axion of modern chemical and technologic research that the materials produced and the forms of energy harnessed must be as well understood for their biological potentialities as for their physical and mechanical properties. It is equally important that other man-made factors in the human environment, including those which we cannot foresee at this time, should be examined critically for their harmful potentialities, in the full recognition of certain facts of life and death, which have recently come upon some of us with a shock. It is clear that reckless man can turn loose and build up physical forces which may destroy himself and his kind. It seems probable, however, that the same ingenuity which thus far has enabled him to explore and to penetrate other secrets of nature, will serve his need when expended in learning more of his own vulnerability and in developing the means for self-protection.

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TWO PAPERS ON WATER SUPPLY PROBLEMS

RESEARCH PROBLEMS IN WATER SUPPLY

by

Harry E. Jordan

A visitor to the United States from Australia, during midyear 1957, pointed out to me that, in the opinion of the Australian engineers, the water resources potential of that continent cannot subsist more than thirty million people at the present rate of use - with all of the foreseeable conservation developments completed, short of saline water conversion. When we realize that the total land area of Australia is only 200 square miles less than the land area of the United States, we should realize more than ever the priceless gift of water that the inhabitants of North America have received.

Most of our country's land area is blessed with reasonably distributed and adequate rainfall and, up to recent years, most cities, with the exception of Boston, New York, San Francisco and Los Angeles, and a few others, have been able to provide themselves with adequate water supplies from the flowing streams, the lakes, or from ground sources. However, the increase in population, as well as the increased per capita use of water, is bringing many other cities face to face with the necessity of water storage and water conservation. The development and extended use of water storage reservoirs is limited by a type of pollution to which most of us do not give consideration. It is, however, a very serious type of pollution - the silting of water storage areas by runoff from the agricultural land tributary to the reservoirs. The Department of Agriculture is making a noble effort to bring home to farmers awareness not only of the losses which accrue to them because of the waste of fertile top soil, but also of the damage that they are doing by allowing the top soil in off-crop seasons to be water-washed and wind-scoured and carried down the small streams, either directly to the ocean or to settle in storage reservoirs which some municipality may have built on the lower reaches of the stream. In the Carolinas, in Texas, and in Illinois, several water storage reservoirs provided for municipal needs have lost their capacity because they were filled up with the silt from the fertile fields upstream.

Water and Pathogenic Diseases

It is normal for us in the water supply field to think of water pollution in terms of human wastes. More than fifty years ago, when I entered the water treatment field as a youngster just graduated from college, many American cities suffered annual death rates from typhoid fever of fifty or seventy-five per hundred thousand persons population. These death rates were largely due to the use of inadequately treated or untreated water by our cities. Today, through the advances in water treatment, the improvement in milk supplies, and other environmental factors, the average physician rarely sees a case of typhoid fever.

Since 1908, the use of chlorine and chlorine compounds has made it possible for water treatment engineers to reduce to a practical zero point the number of coliform organisms present in the municipal supply. There remains an area of substantial lack of correlated information concerning the possible transmission of virus infections through drinking water. It is very clear that we need a great deal of research which will explore the life expectancy of virus outside the human host. We also greatly need to know what paths the virus may follow and what treatment hurdles it may evade in a presumed path to a human being who may be adversely affected by it. We do know of summer camp outbreaks of hepatitis, in the Pocono Mountains in Pennsylvania and under like circumstances in Virginia, where the toilets provided for those resident in the camp were found, after the hepatitis outbreak occurred, to drain rather directly into the well which supplied the camp with drinking water.

There is also the report of the outbreak of hepatitis in New Delhi, India, which, by word of mouth, has been widely discussed in the United States, where some ten thousand cases of hepatitis occurred. Circumstances frequently referred to are, for example, a modern water treatment plant, including coagulation, rapid sand filtration and coagulation, where the continuity of events indicated clear transmission of hepatitis virus in the drinking water. However, there are certain related facts in the New Delhi case which indicate that we cannot properly speak of the case as a breakdown of water treatment installations and equipment, but rather, a breakdown of proper administration and control of the operations. Due to certain dredging operations in the stream bed, the flow of water from an upstream heavily-polluted small stream was turned so that it flowed directly downstream to the water supply intake. The men in responsible charge of operations at the water treatment plant apparently followed directions concerning the treatment procedures derived from the city Board of Health, located at some distance away in the city. There can be no more fatal failure in the administrative control of a water treatment plant, in these modern days, than to place the responsibility for directions concerning details of change in water treatment and chemical dosage on a far-removed laboratory staff. The man in responsible personal charge in a water treatment plant at any hour of the day or night must be provided with basic directives that make it possible for him to adjust the rate of flow in the plant and the dosage of chemicals applied at any moment when tests made by him indicate the necessity of a change.

Control of Water Treatment Processes

There is no man who has been in responsible charge of a water treatment plant who does not remember, in his own experience, the occasional failure of personnel to follow implicitly the directions which had been given to them by the responsible executive. The worker element in water treatment will be remembered by many of us as the weak link in the chain of performance which adversely affected the performance of water treatment works.

There is a British example of the value of automatic control of chlorination which is perfectly germane to this discussion. On a certain ill-fated Friday afternoon the workers in a chemical plant along a stream later used for water supply in two cities dumped a vat of highly offensive waste material into the stream and went on their merry way for a restful week end. One downstream city with a well-controlled water treatment system depended upon laboratory staff observations of the efficiency of chlorination

The unusual load derived from the chemical wastes was not observed until the water had passed through the treatment plant and reached the consumers, who found their Saturday morning tea undrinkable. It required the entire week end of emergency operations of the engineering crew of that city to recover from this adverse event. The other city deriving its supply from the same stream had installed an automatic residual chlorinator and suffered no ill effects, because the machine automatically adjusted the dosage to meet the increased chlorine demand. The satisfaction of the chlorine demand eliminated the taste-producing qualities of the polluted water. The water users in that city knew nothing of the circumstance. In the writer's opinion, there is no more important element in the water treatment installations of any substantial city than the installation of an automatic residual controller for chlorine dosage.

At the present time, high-level research is being carried on, both in England and in the United States, studying the nature of the coagulation process in water treatment, and parallel with that, steps are being taken to develop automatic control of coagulation, so that this important step in water treatment can be freed from the possible failure of personnel to maintain an awareness of the changes going on in water quality. Better understanding of the nature of the coagulation process and the development of automatic equipment for control of coagulation, in the writer's opinion, are the two next great steps in water treatment.

New Coagulant Aid Materials

There has in recent years come upon the market a series of materials which are colloquially called "coagulant aids". There is a substantial need for them. A generation ago, stream pollution was a simple combination of human sewage and soil wash. Today modern industry, particularly the chemical industry, is adding to the burden of the streams a great variety of waste materials, most of which become known to water treatment engineers only because of the adverse effects they have upon the operation of a water treatment plant. They do, however, bring about in the water a resistance to coagulation which can be overcome by the use of the special materials now marketed to assist or improve the characteristics of coagulation. The United States Public Health Service has very wisely set up a special committee to evaluate these materials, primarily from the standpoint of possible toxicity, because there are some which are known to have adverse potentialities. This committee has already acted to approve the use of certain materials. Some which are known to have been produced have not been submitted by their manufacturers for study by the committee, and, at the present time, their use is not approved in the treatment of public water supplies. The allover value of coagulant aids, however, is unmistakable, and there needs to be a joining of research and production to the end that water treatment engineers have available these valuable assistants to their efficiency of water purification.

New Chemical Water Contaminants

A sizeable and very significant addition to the category of water-polluting materials has developed in the form of waste detergents used in the urban households. As an alternate to soaps, detergents have grown in use until the tonnage produced annually is equal to or greater than soap production. The utility is so great that we cannot expect their use to lessen. Collectively, waste detergents have become a serious problem in the operation of sewage treatment plants. In streams where the presence of municipal sewage is a significant factor, the density of detergent wastes, as in some of the Missouri Valley states, as well as in England, becomes a very serious problem. As an alternate to soap, detergents hold in solution the calcium and magnesium which would become a curd if soap was used. Detergents are dispersing agents. Their general action is antagonistic to coagulation. In water where the amount of detergent waste is significant, the functioning of ordinary coagulation processes in water treatment is interfered with. Both in the United States, as well as in England, highly competent research groups are studying possible changes in the composition of detergents as well as the lessening of their adverse effects in water into which they have been thrown as waste materials. To a degree, related to the extent of the use of detergents on a watershed, they present a problem of very substantial significance in water pollution. The producers of these materials employ competent men who are cooperating in research with the United States Public Health Service and with the water works industry, but that cooperation has not as yet clearly chartered the pathway to a correction of the difficulty derived from their use.

Of far greater magnitude, dollar-wise as well as tonnage-wise, is the addition to water pollution by the use of insecticides and antibiotics. To one who has not had immediate contact with the Food and Drug Administration's consideration of various insecticides, the perusal of a ten-page listing of crude materials issued as of March 1, 1958, by the Food and Drug Administration is a somewhat devastating revelation. From the simple composition of lead arsenate, one travels through the tremendous list, beginning with DDT, carrying on with Dieldrin, Malathion, Chlordane and dozens of other materials, now used to protect our fruits and vegetables against insect devastation. This latest problem of water pollution derives from the very simple fact that these materials eventually are washed off the fruit and vegetables and find their way either into the surface streams or into the ground water. I quote from a statement titled "The Problem of Chronic Toxicities of Non-Nutrient Substances", presented to the National Advisory Health Council, and containing these words:-

> "The problem presented may be stated briefly as that of the possible chronic toxicity of non-nutrient substances habitually entering the body in small amounts. Included in the problem is the possibility that any two substances, when present together, may have a synergistic toxic action, greater than the sum of their separate toxicities. An instance recently discovered in the field of insecticides is a case in point. Malathion and EPN have been found to be many times more toxic when fed together to rats than was expected from their separate toxicities. There is also the possibility that infants, or pregnant mothers, or persons below par in health, or unduly fatigued, or undernourished - may be more susceptible to a chronic toxic action than persons in a more nearly average state of health or activity."

In addition to the possible dangers derived from the direct consumption of the food products which may contain residues of these insecticides, we are substantially uninformed concerning the mass effect upon water quality in streams which may derive from the run-off from fields in food-raising states such as New Jersey, Florida, California, and others, where surface water - and especially ground water - may become polluted with these materials to the extent of significant toxicity to human beings who may drink water derived from such sources.

The Food and Drug Administration has set what it considers, on the basis of the evidence presented to it, safe tolerances for the residue of the insecticides which may be left on the fruits and vegetables. It has not and can hardly be expected to consider the derived problem of water pollution which follows the rainfall on the fields and orchards where these materials are used. The manufacturing chemical industry bears a heavy responsibility in this field. While the products of their research and operation are of great benefit, the problems derived from water pollution from such materials may become of very significant magnitude. The manufacturing chemist, as well as his partner in other heavy industries, is not greatly inclined to be concerned over the waste products from his own operation which may adversely affect water quality flowing in our streams. We are pretty well advised that the most serious problem that the Ohio River Sanitation Commission faces is not the problem of sewage derived from human dwellings and activities, but those waste materials from industry which do not lend themselves to conversion to harmless form by recognized methods of waste treatment.

The water supply engineer finds himself somewhat in the position of the rabbit in "Alice in Wonderland" - being compelled to work twice as hard to run twice as fast to keep up with the deluge of the previously unknown chemical compounds that industry either produces for sale or develops as a by-product of other production and adds to the burden of stream pollution. Whatever else may be said, this is not a time for complacency - it is not a time for contentment over advances which have been achieved during the last hundred years - it is not a time when we can seriously look forward to the end of our worries and to the end of our problems. New worries are hiding right around the corner and new problems are being brewed in our industrial plants.

* * *

WATER SUPPLY RESEARCH

by

M. D. Hollis

If the past be prologue, there is ample support for the contention that water resource and its management shape the destinies of civilizations.

In this fast moving age of science and technology, perhaps it is well that we pursue our quest for push-button living -- and along with it recognize the potentials of push-button destruction -- but man in his quest must reckon with the consequences of his pursuits on his environment and maintain some order of balance. In the physical environment, water, air and food represent the basic triangle. And, of the three, water thus far in history has been the more dominant influence on man's eternal struggle with his environment.

The report to the President by the Presidential Advisory Committee on Water Resources Policy states that:

> "... water is more than a natural resource - it is a necessity of life. Here in the United States, blessed with a continent of virgin soil, we lived more than 200 years before the water problem became generally acute. But the uses we make of water in modern society are so tremendous that they stagger the imagination. The coming of our industrial era, the raising of our living standards, and the increased application of water to land have now highlighted the problem until in much of the Nation there is a grave and increased concern over water resources".

The report further states that:

> "... the basic elements of a sound policy relating to water are clear. That policy must look toward an adequate water supply for our people, prevent waste of water,

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provide for a greater reuse of water, reduce water pollution to the lowest practicable level, provide means for the useful and equitable distribution of available water supply, and take steps to check the destructive forces of water which threaten to injure or destroy land, property, and human life.

"There have been wide differences of opinion as to the best methods to meet these problems. It is a good omen that these differences are so generally discussed".

Water, today, is a matter of top priority as population growth and industrial expansion shape large sections of the Nation more and more into a continuous complex of metropolitan and industrial centers. The average urban per capita use of water is well above 150 gallons per day. When we add to this the water required to produce the things we eat and wear and use, this per capita per day requirement goes above 1200 gallons. Predictions are that the total water requirements will double by 1975.

My assignment today is to comment on water supply research. As we view it, our research needs may be stated in simple terms: to augment supplies of water by novel means, to reduce water loss, and to treat polluted water for reuse.

Water Supply Augmentation

It seems likely that by 1975 the use of converted sea water for water supply augmentation in coastal cities will be feasible and perhaps even routine. Although technical problems are still troublesome, novel methods under study offer promise that the inexhaustible supplies of the ocean may be effectively and economically tapped. At present, costs of converting sea water in full scale plants employing distillation, the most efficient process, vary from $1.75 to $2.80 per 1,000 gallons (1). The goal is $.30 per 1,000 gallons. However, with practicable measures in the offing, continued support should be given to research on sea water desalination.

The huge quantities of water in the atmosphere should not be ignored as auxiliary sources of supply. The average annual water content of the air above the eleven Western States is in excess of 1 1/4 billion acre-feet (2). While present weather modification technique may be crude and ineffective, we must accept its scientific soundness and potential feasibility. This view is supported by the President's Advisory Committee on Weather Control which concluded that cloud seeding produced an average increase in precipitation of 10 to 15 per cent in certain mountainous areas of western U. S. (3). Further research on mechanisms of recovering water from the atmosphere should be encouraged.

Conservation

A substantial part of our future water needs may be met by conservation of the water reaching us. Wastage of flood waters to the sea, and uncontrolled losses by evaporation, suggest profitable areas of water saving. The development of practicable conservation methods is already an important research goal. Such research should be expanded and intensified, particularly on high rate recharge of aquifers, and on the use of monolayers on water surfaces.

Recharge

It is a most interesting fact that a 10 foot stratum of sandy soil of average porosity underlying a watershed will hold the greatest single flood flow likely to occur on that watershed. Unfortunately, we have no way at this time to make effective use of water bearing strata in flood containment and water conservation. However, we may be justified in the belief that more intelligent use can be made of our great underground reservoirs to supplement conventional surface storage.

Evaporation Reduction

Loss by evaporation represents a most frustrating form of pure water wastage. It is indeed sobering to realize that the water lost by evaporation in the U. S. exceeds the amount taken for use in cities and towns. It has been estimated that evaporation from storage units now under construction in the Colorado River system will equal more than one-third of the replacement storage they will provide. (2) Obviously, the development of practicable ways of reducing evaporation is a matter of importance in public health. Research recently undertaken on the use of monomolecular films of long chain fatty alcohols to suppress evaporation is therefore significant. Both theory and pilot field studies support optimism concerning the ultimate ability of hexadecanol or other suppressants to reduce evaporation, perhaps as much as 50 per cent.

Water Treatment

Although the possibility of developing novel sources of water supply should be thoroughly evaluated and exploited, the primary effort in water supply research must continue to be the development of new and improved processes for reclaiming sufficient water to meet the requirements of all intended uses.

Organics In Solution

We are all familiar with the growing problem of contaminants in solution. Such materials are closely associated with the manufacture and use of the products of our technological economy. They may originate in sewage as do detergents; or they may occur in land drainage as do fertilizers, insecticides and other agricultural poisons; or they may be deliberately applied to water for plant or fish control. The bulk of man-produced organic chemical contaminants reaching streams is discharged through the Nation's sewers. Conventional water treatment plants are not well equipped to cope with many types of such materials.

An inventory of the specific synthetic organic chemicals contained in drinking waters derived from inland waterways would, I suspect, startle most of us. At this time, it is not possible to make such an inventory. Even with application of the most advanced techniques for analysis of organic chemicals, it is doubtful that all unknown compounds could be identified. However, we may speculate further on this situation.

The treated drinking water of a community contains, among other substances, an intricate mosaic of stable organic chemical structures which reflect the past history of the supply. These compounds may or may not manifest themselves by producing taste and odor. To this burden of chemicals, the community adds its increment of solids, including soluble, persistent, non-oxidizable compounds like the alkyl-benzylsulfonate component of detergents. It is worth noting that by 1956 the Nation's production of detergents had risen to some 3 billion pounds per year. This production rate is expected to double within the next decade.

Drainage from land treated with insecticides, weedicides, and other materials, inevitably adds to the stream's load of persistent organics. These organic materials are being recovered from all parts of the main stem of the Mississippi River. DDT, in a concentration of 5 parts per billion was recovered from Lake St. Clair on the Canadian boundary. Health agencies, as well as conservationists, are following with concern the Department of Agriculture's large-scale, intensive fire ant control operations in the Southeastern States where dieldrin and heptachlor eventually will be applied to some 30 million acres of infested land. To date, 80,000 acres have been treated at a rate of 2 lbs. of insecticide per acre. By July 1958, 450,000 acres will be under treatment. Again, we may note with interest that U. S. production of pesticides and other organic agricultural chemicals rose from 125 million pounds in 1947, to some 570 million pounds in 1956.

Ground waters are subject to organic pollution in the same ways as surface waters. A recent report of shallow well pollution by endrin, a chlorinated hydrocarbon applied to orchards to kill field mice, suggests that this problem may become highly significant. We can ill afford to ignore this new dimension in contamination by synthetic organic chemicals.

Improvement of impoundments, including municipal water storages, for recreational use is also influencing the character of drinking water. A number of cases have been reported recently of the use of fish poisons to control coarse, undesirable fish in these reservoirs. The organic chemicals used for this purpose obviously impose a new burden on the water treatment process and add to the total organic complex in the treated water.

It is now realized that conventional yardsticks of pollution, B.O.D. and coliforms, give few clues to the presence of these synthetic organic pollutants. The intricate structure of most compounds, the complex nature of mixtures, and the paucity of knowledge of chemical reactions in dilute solutions, preclude the use of even sensitive analytical procedures. We may ponder the fact that the great bulk of the new chemical contaminants reaching our treated water supplies give no obvious sign of their presence. It is probable that detergents in water supplies would be unsuspected if not for the visual evidence they produce.

Advanced studies on adsorption, if undertaken, may indicate useful supplementary treatment for municipal water supplies. Methods for separating dissolved solids from water, now being investigated in connection with desalination, also may be effectively applied to the problem of removal of contaminants. High priority for such research is strongly justified.

Toxicity

The toxicological significance of organic chemicals in drinking water supplies has not yet been adequately evaluated. Long-term use of such water, like long-term exposure to organic chemicals in other phases of the environment, may conceivably produce personal health impacts. Although evidence at hand offers little clue to the existence of these effects, it must be assumed that a limit exists to human accommodation for such substances. Sound public health practice requires that this potential threat be anticipated, evaluated, and, if necessary controlled.

Complex mixtures of organics recovered from raw and treated municipal water supplies are being examined at a few research laboratories. If evidence of toxic potential is recognized, epidemiological investigations should be conducted to determine whether the presence of these materials in drinking water may be associated with incidence of illness.

Because of the very high cost for toxicological evaluation, a short-time presumptive test to determine the chronic toxicity potential of specific or complex materials is required. Competent agencies are urged to undertake such research.

Particulates

While the concentration of dissolved contaminants may be expected to continue to increase, the familiar problem of particulates cannot be ignored. One of the most surprising findings in the recent Chanute, Kansas, study was the large amount of organic debris of particle sizes up to 20 microns appearing in the filtered water. We have known for some time that the efficiency of filtration was markedly reduced for particles in the virus size range. It was not suspected, however, that relatively large particles could get through, even under stress of continued heavy particulate loadings. This observation supports the opinion that a critical reviewof filter design criteria is in order.

These criteria have not been changed in any important respect in the last generation, in spite of considerable study and new knowledge gained. Recent information indicates that the conventional rapid sand filter is less effective than properly controlled chemical coagulation in turbidity removal, and less reliable than break-point chlorination for microorganisms. Yet the filters are the most costly component of the purification process. Urgently needed are studies to determine the relationship between filtration rate, sand characteristics, sand depth, and efficiency of removal of particles of various sizes.

Viruses

Reports of the transmission of infectious hepatitis virus through contaminated water give further emphasis to the need for critical evaluation of conventional water treatment practices. Assessment of the public health aspects of viruses in the water environment requires improved methods for recovery, identification, and enumeration of viruses especially with reference to water treatment. Particular emphasis should be given to development of a tissue culture technique for growth of infectious hepatitis virus, as this has not yet been successfully cultured outside the human host. In view of the importance of this problem, all agencies are urged to join in this research.

Conclusions

We are examining here some bed rock problems of water supply. Let us, therefore, be brutally frank with ourselves and consider the following:

1. Should we concede that the identification of unknown substances, inert organic or viable, in water is too difficult a problem for us to resolve in routine fashion?

2. In view of this difficulty, would it be practicable to place the requirement of complete purification of waste on the polluter?

3. Are we giving sufficient attention to the possible adverse additive effects of foreign materials in drinking water?

4. In view of our apparent good urban health, are we magnifying unduly our water supply problem?

5. On some of the problems cited, our concern admittedly is a potential one based somewhat on ignorance, especially with respect to toxicological implications.

This represents only a brief view of some of the more pertinent highlights in the area of water supply that desperately need research evaluation. We must keep foremost in mind that we move forward in an unprecedented technological era, with a reduced time factor for equating environmental health impacts. No longer should we depend entirely on the traditional evaluation of statistical records as a guide to health practice. The type and rapidity of change require much keener vision in anticipating public health impacts, with our research effort geared accordingly. Even so, likely the professional judgment factor will have to be applied in many instances. But as promptly as is feasible the supporting data, through research, should be developed.

References

(1) E. D. Howe, Saline Water Conservation. Jour. Amer. Water Works Assn., 50: 319. March 1958.

(2) Control of Evaporation Losses, Memorandum of the Chairman to Members of the Senate Committee on Interior and Insular Affairs. Committee Report No. 1, April 14, 1958.

(3) Final Report of the Advisory Committee on Weather Control. Vol. 1, Submitted December 31, 1957.

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TWO PAPERS ON WATER POLLUTION PROBLEMS

WATER POLLUTION - THE SCOPE OF RESEARCH NEEDS

by

J. E. McKee

As stated so ably by Rush (1): "Man, a single species, has become an important geological and ecological influence on the earth, and his powers over the environment are increasing precipitately... He threatens to sweep from the earth whole orders of life, and in doing so he may initiate irreversible changes that will sweep him off also. Man is fast outgrowing the planet."

The products of man's activities, and especially the magnitude and diversity of his solid, liquid, and gaseous wastes, are increasing at an accelerating rate with the improvements of technology, advancing industrialization, and ever-expanding populations. These products and wastes create an impact upon the environment and affect the ecology of all living creatures, including man himself. Some of these effects are vivid and acute; but most of them are so masked and subtle that they do not become apparent until after ecological or genetic damage has proceeded beyond a point of rejuvenation. Nowhere are these effects more complex, more diversified, and less understood than in the pollution of our water resources by liquid wastes from municipalities and industries. To assess these effects and to attempt to control them is a major undertaking for sanitary engineers.

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(1) J. H. Rush, "The Next 10,000 Years," Saturday Review of Literature, January 25, 1958.

Traditional Patterns For Pollution Abatement

The advent of water pollution is seldom sudden. Indeed, the discharge of liquid wastes to a body of natural water does not constitute pollution (as defined in many statutes) until such discharge becomes unreasonable and adverse or inimical to the beneficial uses of the receiving waters. The threshold of this condition is difficult to determine, for there is a large area of gray between the white and the black.

In the normal history of stream degradation, many initial discharges of liquid waste are so minor that they show no apparent effect upon the stream. As the wastes increase in quantity or strength, pollution becomes evident and then possibly acute. Finally, a regulatory body or a court of law takes action to force abatement in accordance with local statutes or riparian law. Rigid standards are frequently followed in establishing the degree and design of treatment, for such action is administratively convenient and conservative. With time as the essence, abatement will be accomplished to a large extent by conventional processes of treatment. As a last step, someone may get around to research or other investigation of the polluting mechanisms, the assimilative power and ecology of the receiving waters, and the integration of the entire water system. In effect, then research lags behind practice and abatement.

There are, to be sure, many instances where regulatory action has been hamstrung by politics, by ineffective or inadequate laws, or even by fact that no known methods of treatment are within economic feasibility. Here, research may be instituted as an interim measure, possibly even as a delaying tactic.

This normal sequence has been modified, fortunately, in several enlightened states and interstate agencies. Case-by-case studies, based on a thorough evaluation of the entire water system and its economic uses, lead to tailored requirements or specifications for each discharge of industrial or municipal waste. Such studies, however, must still be founded upon known procedures or techniques, with little time or budget for true research. Yet intensified research is vitally needed if the mounting effects of man's impact upon water resources are to be controlled.

Fundamental Vs. Applied Research

Before considering specific items or even broad categories of research, it might be well to reflect on the nature of research. In our postwar economy, research has become a popular byword, often bandied about without appreciation for its true meaning. Research is the quest for new knowledge, generally by critical and exhaustive investigation or experimentation. It is not the development of instruments, gadgets, and equipment nor is it the application of known procedures to the accumulation of routine data.

Research may be fundamental or applied. Fundamental research asks the question "why?" and to answer this question it generally relies on mathematics and the basic sciences (physics, chemistry, biology) or possibly upon engineering sciences (fluid mechanics, thermodynamics, etc.). It is largely the domain of the university. Frequently it has no practical significance, but it adds to the storehouse of our understanding of natural phenomena.

Applied research is more concerned with "how?", "how much?" or "to what extent?" It frequently involves engineering practice, economics, psychology, and many related disciplines. It is the realm of the research institute, the government laboratory, the large corporation, or even the practicing engineer.

Do not believe for a moment, however, that the division between fundamental and applied research is rigid or sharp. Many new fundamentals find their way rapidly into important practical applications. Conversely, much of our storehouse of basic science has evolved from engineering practice and measurements, especially when an investigator inquires "why does this happen?" If he cannot answer this question satisfactorily from engineering data, he calls upon the basic scientist for assistance. Thus, much of the stimulation for fundamental research is attributable to the inquiries and demands of applied technologists. Research can be a two-way street.

Research problems in the control of water pollution can be divided into three main categories: 1. Specific research problems, involved generally with a special phase of waste treatment or the effect of a polluting substance on the quality of receiving waters.

2. Broad problems representing a wide spectrum of interests but with a strong central theme or objective. 3. Problems related to the promotion, administration, conduct, coordination, and application of such research. It is the aim of this paper to explore the first and second categories, while Dr. Ralph E. Fuhrman will discuss the third category in the next presentation.

Specific Research Needs

With these thoughts in mind, let us consider some of the specific and critical research needs in water pollution. We shall not be the first group to do so. The Committee on Research of the Federation of Sewage and Industrial Wastes Associations has been especially active in this respect. Each year it publishes a critical review of the literature on sewage, waste treatment, and water pollution. This review serves to stimulate the reader to new avenues of investigation. In 1954, the Committee published the results of a survey of current research problems, based on the interrogation of 145 carefully selected technologists in water pollution. To assist in discussion at our conference, 14 especially pressing problems enumerated in this survey have been reproduced as Appendix A herewith. The original article contains 73 additional suggestions under major topical headings.

A suggested program for productive research in waste treatment and disposal was prepared in 1953 by Dr. H. A. Thomas, Jr. and approved by the National Research Council, Division of Medical Science, Committee on Sanitary Engineering and Environment. Extracts from this report are attached hereto as Appendix B. The National Technical Task Committee on Industrial Wastes polled its membership in 1956 and compiled a list of urgent research projects in the order of their priority. This list is included herewith as Appendix C. The ASCE Committee on Sanitary Engineering Research has been active in stimulating such research and publishing the results thereof, but no condensed list of research needs has been released as yet.

Recent Suggestions

To supplement these published lists, to bring them up to date, and perhaps to uncover a new philosophy of research, the writer requested 15 prominent sanitary engineers (many of whom are present at this conference) to submit suggestions. Despite an extremely short time limit, 80% of the engineers responded with scores of excellent research ideas. Their courtesy and splendid cooperation are deeply appreciated and gratefully acknowledged.

Many of these suggestions duplicated or overlapped in part the problems already listed in published documents; hence they will not be repeated here. The reply from Bernard B. Berger, Chief of the Water Supply and Water Pollution Control Program at the Sanitary Engineering Center (USPHS) was so comprehensive and detailed that it is reproduced herewith for discussion purposes (Appendix D). This reply embraced many of the suggestions submitted by other respondents, and it also covered many items of research at the Center, current and proposed.

Dean Gotaas and Professor Fair brought up the question of "operations research" or "systems analysis" in connection with entire drainage basins, whole treatment plants, and all inter-related problems of water resources. Modern computing machinery will enable the engineer rapidly to integrate the complicated effects of many variables upon the system as a whole, to give the maximum good at the least overall cost. This technique is especially applicable to the control of water pollution.

Several respondents stressed the importance of fundamental studies in surface chemistry, colloids, adsorption phenomena, and gas transfer. Others concentrated upon the need for knowledge about new organic chemicals, their rates of decomposition, and their effects upon receiving waters. To these needs should be added an evaluation of possible genetic modifications upon man and aquatic life.

It will not be possible to evaluate all of these specific research needs in detail at this time. Perhaps the group discussion at this Conference will be able to sort them out and determine the most critical ones.

Broad Problems of Research

Many of the specific research needs can be grouped into broad problem areas. Indeed, certain specific research efforts will benefit several of the broad areas. Let us consider some of the major categories of research on the comprehensive plane.

1. Reclamation and Reutilization of Waste Waters

In the opinion of this writer, the most important research needs in water pollution are those that arise from the reclamation and reutilization of waste waters. Acute shortages of fresh water, long a problem in the arid West, are beginning to plague humid areas of the Midwest, East, and South as the demand for water skyrockets. Man's greatest impact on his environment as related to fresh water is his increased demand for this substance and his reckless pollution and abandonment of once-used water.

A major research effort is under way to develop economical methods for desalting sea water, containing about 35,000 mg per liter of dissolved salts; yet we are discharging daily to the ocean billions of gallons of once-used fresh water with less than 1,000 mg per liter of total solids. The cost of reclaiming such waste waters will always be a fraction of the cost of desalting sea water.

Among the consequent problems demanding new or improved knowledge are the following:

a. The survival rates and destruction mechanisms for all types of pathogens in various treatment processes.

b. The calculated risk in health hazards and other detrimental effects associated with utilization of waste waters for irrigation, recreation, stock watering, and perhaps even for human consumption. Many existing codes that restrict such reutilization are founded on a wide margin of safety, compounded by ignorance.

c. Mechanisms for the removal or inactivation of sulfates, nitrates and phosphates, especially in waste waters being used for ground-water recharge. It is probable that tertiary (or polishing) treatment will be needed at many waste-water facilities.

d. The modifications of polluted water as it flows through porous media of various geochemical composition, and conversely, the effect of such water upon soil structures. Many problems arise from the spreading, percolation, and recharging of waste effluents.

2. Ecology of Receiving Waters

The limnology and rheology of fresh water have been studied intensely; but much more work needs to be done, especially in relation to new synthetic organic substances and radioactive wastes. The effects of waste discharges on the marine and estuarine environments, however, have not been investigated with comparable thoroughness and, as a result, ecological data relating to such effects are sparse. Research in this broad category involves study of pelagic and benthic biota, mechanisms of diffusion and dispersion as they relate to flushing and mass transport of pollutants, factors governing the survival and destruction of pathogenic organisms, and many other specific problems.

3. Integration and Coordination of Water Pollution Control With Water Resources Management

To achieve optimum economy, it is essential that the assimilative capacity of receiving waters be utilized to the utmost without unreasonable damage to the beneficial uses of the water. Such economy demands a careful balance of the costs of waste treatment and the dollar value of any degradation in water quality. This balance can only be achieved by an analysis of all factors involved in the water resources of a drainage basin. The new electronic computing machines can be used effectively in such analyses.

4. Development of More and Better Research Personnel

At a time when the research needs in environmental health control are mounting rapidly, the supply of personnel trained and training for research in this field is dwindling. The reasons for this decline are too numerous and too complex to describe at this time; but they are generally known to this audience. The present trend must be reversed quickly and decisively if the research needs in water pollution control are to be met effectively. Financial incentives will be needed to draw more engineers and scientists into this field. Efforts should be expended to bring in scientists of related disciplines, e.g. biologists, chemists, and oceanographers. Finally, sanitary engineers themselves must be given a stronger training in the basic sciences and mathematics.

APPENDIX A -- RESEARCH PROBLEMS IN NEED OF STUDY

Abstract from: "A Survey of Current Problems For Research"

by H. Heukelekian and W. H. Wisely

Sewage and Industrial Wastes 26, 1155 (1954)

1. Synthetic detergents: Effects on sewage treatment processes and on sources of water supply; oxidizability of all types; causes, effects, and control of froth formation; effects on grease content and removal; combined effects with shredded garbage from household grinders; comparison of effects in hard-water and soft-water regions.

2. Toxicity in biological treatment processes: With special reference to cyanides, chromium, copper, zinc, nickel, iron, cadmium, oils; limits under shock dosages and under continuous dosages.

3. Toxicity in natural waters: Limits for various compounds and wastes separately, as well as synergistic effects of mixtures as discharged to receiving waters.

4. Biological treatment processes: Mechanics of removal and synthesis of organic pollutants (use of radioactive tracers suggested); identification of microorganisms, development of optimum-yield cultures; modifications to permit applications to treatment of strong industrial wastes.

5. Stream pollution criteria: Development of specific yardsticks for measuring degree of pollution.

6. Pathogenic organisms: Development of improved technique for accurate enumeration in sewage and polluted waters; application of molecular filters to determination of E. coli and enterococci.

7. Hydrogen sulfide: Mechanics of formation; development of effective and economical control methods.

8. Pre-aeration: Fundamental mechanics of process; evaluation of advantages, both as to effectiveness of treatment and from standpoint of economics.

9. Aeration: Fundamentals of oxygen transfer and diffusion; development of improved methods.

10. Sludge digestion: Continued study of mechanism of process as means for accelerated treatment.

11. Sludge concentration: Development of improved methods, perhaps by continuous centrifuge, air or gas flotation, or by elutriation; study of viscosity and thixotropy of very dense sludges as a means of developing improved methods of pumping and movement in channels and piping.

12. Undigested sludge dewatering: Feasibility of methods of disposal of raw sludge cake; development of improved dewatering methods.

13. B.O.D. determination: Continued efforts to develop an accurate rapid standard method applicable to all non-toxic organic wastes.

14. Radioactivity in sewage and sludge: Assembly of data on background concentrations of radioactive substances in municipal sewage works; effects on biological processes; hazards to operation personnel.

APPENDIX B -- RESEARCH PROBLEMS IN NEED OF STUDY

Abstract From: "Productive Research in Waste Treatment and Disposal"

by H. A. Thomas, Jr.

Sewage and Industrial Wastes 26, 121 (1954)

RECOMMENDATIONS

Five broad avenues of advance are presented in the following outline that, it is believed, will be productive and rewarding. Some specific lines of investigation are noted; these are intended to be suggestive rather than exhaustive.

1. Thorough re-evaluation of indices of pollution and contamination.

    (a) Continued research on biochemical oxygen demand, coliform, and other similar tests are desirable, but not to such a degree as to exclude a search for newer and more significant determinations.

    (b) Better methods and perhaps substances for disinfection of sewage and other contaminated wastes.

    (c) A critical examination of the significance of aftergrowths in receiving waters subsequent to disinfection.

    (d) Further delimitation of pathogen survival times.

2. Added emphasis on methods of evaluating pollution load capacities of streams and concomitantly on improvement in the art of plant design to attain stipulated amounts of treatment.

    (a) Improved methods of aeration, possibly with air injection at supersonic velocities.

    (b) Application of principles of fluid mechanics to problems of mixing and short-circuiting of flow in tanks and streams.

    (c) Development of a satisfactory continuous dissolved oxygen recorder for use in stream surveys.

    (d) Centrifugal storm flow separators for combined sewer overflows.

    (e) High-rate sludge digestion (anaerobic activated sludge).

    (f) Wet sludge incineration in high-pressure tanks.

    (g) Model artificial streams to facilitate study of effects on new types of waste in stream ecology.

(h) Use of pure oxygen in sewage treatment.

(i) New processes for control of nitrate and phosphate in sewage plant effluents.

3. More effective and economical waste treatment and disposal methods for small and isolated communities, especially under adverse conditions of climate, soil, and topography.

(a) Investigation of the clogging process in soils by septic tank effluents.

(b) Development of the "completely aerobic" sewage treatment plant for small installations.

(c) Continued investigation of merits of new insecticides, rodenticides, and animal repellents, to delineate further the role of these ancillary aids to sanitation.

4. Search for feasible modifications of industrial processes, in the factory, to reduce amounts of objectionable waste so as to ease problems of trade waste treatment.

5. Standardization in the technical literature as to (a) symbols and nomenclature; (b) measuring units, such as loading parameters; and (c) forms of graphical representation; as well as (d) methods of statistical analysis and presentation of experimental results."

APPENDIX C -- RESEARCH PROBLEMS IN NEED OF STUDY

Abstract from report on: "Research Priority Selections"

by Task Group

Proceedings of December 13-14, 1956 meeting of NTTCIW

Priority Number	Research Projects
1	Evaluation of all factors including those in nature, which contribute to tastes and odors.

Priority Number	Research Projects
2	Critical examination of methods of analysis for wastes under investigation.
3	Control of tastes and odors due to natural causes so that the industrial wastes problem can be more clearly defined.
4	Critical examination of drinking water standards.
5	Realistic chloride limits.
6	Pathways to biological stabilization of industrial wastes.
7	Studies of sanitary quality of wastes used for spary irrigation.
8	Identify and characterize wastes which are toxic to algae and invertebrates.
9	High pressure oxidation of organic wastes from industry.
10	Limits of radioactivity for various uses of water.
11	Methods for predicting the effects of wastes on the palatability of fish.
12	Stimulate natures purification processes.
13	Biological indicators of water impairment and recovery.
14	Use of radioactive isotopes as tracers in the dispersion of waste effluents.
15	What can be done to prevent heavy fish mortality due to natural causes.
16	Standardization of laboratory equipment for study of biological treatment.
17	Diffusion in bodies of water.

Priority Number	Research Projects
18	Treatment at water supply plants rather than at the sources of wastes to realize lower cost due to natural purification and dilution processes.
19	Investigation of new processes for treatment of wastes.
20	Synergistic effects of wastes.
21	Effects of wastes from the paper and alkali industries on irrigation and stock watering.
22	Effects of slugs of wastes on aquatic life.
23	Determine the physiological as distinct transitory psychological effects of chlorides.
24	New types of wastes which should be investigated.
25	Disposal of brines.
26	Effects of uncontrolled violence of floods on natures purification processes.
27	Reclamation of water from impoundment of tailings from the mining industry.

APPENDIX D -- RESEARCH PROBLEMS IN NEED OF STUDY

Suggested Research Needs in Water Pollution
by Bernard B. Berger 1958

Analytical Methodology

Development of procedures for absolute identification of chemical components of wastes from new industrial processes. The complexity and variability of operations in the growing chemical industry are reflected in the character of the plants' wastes. Monitoring of such complex wastes is not feasible in terms of specific chemical structures contained, or on the basis of oxygen demand. A procedure which would identify and measure the elements contained in the waste rather than chemical structures, offers an approach that should be explored.

Development of improved methods for recovery, concentration, and identification of specific substances occurring in trace concentrations at points of water use. Stream surveillance and effective evaluation of pollution conditions require the availability of highly sensitive methods for sampling, concentrating, and identifying materials present in the water. The Center has developed the carbon filter which appears to be an acceptable sampling device. We, and others, have employed fractionation, chromatographic, spectrophotometric and other highly refined procedures to the identification of specific chemical structures of importance. Additional effort should be given to the development of improved procedures and to their application to specific significant compounds present in trace concentrations.

Development of techniques for recovery, identification and count of water-borne viruses. The role of viruses in sanitation has not been clarified. Although pathogenic viruses may be recovered from sewage and freshly contaminated water, more work is necessary to establish their significance in water. This is particularly true for the virus of infectious hepatitis. A long-range program is being conducted by SEC to improve methods for recovery, identification and enumeration of water-borne viruses. Current investigations are directed to their removability by sewage and water treatment processes. A major need exists for a tissue culture, or other technique for growth of infectious hepatitis virus which, as you know, has not yet been successfully grown outside the human host.

Effects on Water Uses

Development of standard procedure for predicting the persistence and fate of a waste in a stream environment. We are not badly off in predicting the persistence and fate of sewage effluents in streams because we have formulations that represent rational approaches to this problem, and we have many years of engineering experience on which to draw. This is not true for many industrial organics that are not sewage-like in character. We may try to simulate the stream in the laboratory, but we cannot, with satisfactory confidence, extrapolate these findings to the stream. Basic information is necessary on biological mechanisms, physical agencies and chemical reactions application to the degradation of specific industrial wastes in streams.

Development of simple, short-term bioassay procedure for predicting the toxic effect on fish where very low concentrations of waste and prolonged exposure periods are involved. The present commonly used bioassay procedure provides a so-called TLm, the concentration of the substance killing half of the exposed fish following a 48-hour contact period. However, we are not really interested in this concentration. We are more interested in the concentration that may be tolerated indefinitely by highly sensitive forms of fish. Our biologists use an "application factor", usually a factor of one-tenth, for obtaining this tolerable concentration. This is not universally satisfactory. We have evidence that this factor is hardly conservative for certain materials. On the other hand, industry has claimed that it is ultra conservative, and therefore uneconomical and arbitrary. An extension of the current bioassay to provide such information is important.

Development of practical bioassay procedure for determining the toxic effect of waste on fish food organisms. Many wastes are not directly harmful to fish, but may be toxic for their highly sensitive food organisms. The conventional bioassay will throw no light on the damage potential of waste to the fish food chain. The development of a bioassay procedure using important fish food organisms would be desirable.

Fundamental studies in the chemistry and control of taste and odor. Taste and odor conditions represent the most common complaint received by waterworks in the U.S. Wide variation in individual response, as well as subjectivity of response, make evaluation and control difficult. Study should be stimulated to provide further knowledge on the physiological, psychological, and statistical factors involved in taste and odor and on additive and subtractive features of specific important compounds.

Development of methods for controlling pollution resulting from drainage of economic poisons applied to land surfaces. We are confronted here by what might be considered continuous line sources of pollution as opposed to point sources of pollution represented by outfall sewers. The problem is becoming acute. The Department of Agriculture in the Southeast part of the U. S. is engaged in a long-range, large-scale program applying heptachlor and dieldrin to 25 million acres of water shed in an attempt to destroy fire ants. Destruction of highly valuable fisheries may result from this insecticiding operation. A number of cases of such damage have already occurred in other recent insecticiding incidents. Methods for preventing or reducing such pollution are needed.

Determination of the removability of larvicides, algicides, piscicides, and other economic poisons applied to water bodies by conventional water treatment processes. The increasing recreational values reflected in water impoundments is leading to more elaborate and more frequent chemical treatment of these waters for fish management and other purposes. Inevitably this leads to consideration of the threat such chemicals pose to treated drinking water supplies. The Center has received a number of requests for information on the toxicity of these compounds for humans and on the ability of water treatment processes to remove them. It is expected that requests for such assistance will increase in the future.

Determination of self-purification properties of ground water with respect to organic pollution. It is expected that conservation of water by ground recharge will be widespread. It is therefore important to know the degree of hazard presented by water containing synthetic organic compounds. We have already had one experience indicating that endrin, a chlorinated hydrocarbon of very high toxicity to fish, could be recovered from a shallow well in an area where this material was used to control field mice. Other cases of ground water pollution by synthetic organics may be cited. It is important to know whether water traveling through the ground will purify itself and how self-purification applies to specific compounds present.

Development of presumptive tests for determining human toxicity potential of a waste. This problem area is extremely important to sanitary engineering although it obviously belongs in the field of medically related research. However, I feel it is necessary to include this because evaluation of human toxicity potential may be expected to assume increasing importance as the chemical industries expand and population continues to grow. The real problem here is this: an acceptable test for human toxicological properties of a material is time consuming and very expensive. No suitable method is available for quickly screening out materials that may be discharged to water courses requires the availability of a presumptive test.

Treatment

Identification and control of fundamental factors affecting selection and adaptation of communities of microorganisms for most efficient degradation of synthetic organic chemicals. Conventional biological treatment, originally designed to stabilize sewage and sewage-like materials, does not work well for many important industrial wastes. At this time, little can be done to improve the situation because the adaptation of natural seed organisms to do the job is essentially uncontrolled. More knowledge is needed on the kinds, requirements, and control of organisms useful in destruction of organic chemicals.

Further development of practical methods of separating dissolved materials in waste effluents by adsorption. Present methods of using carbon for adsorption are expensive and not always effective. More information is needed on adsorption phenomena and its application to development of new, highly efficient and economical adsorbants. Practical methods are required for regeneration of adsorbants to permit reuse.

Development of practical methods of separating dissolved materials in waste effluents by use of aquatic plants. The use of algae to reduce a waste's content of nitrates and phosphates is not new. However, the difficulty of separating algae from the treated waste poses problems of economy and operation. The feasibility of using fixed aquatic plants should be determined.

Development of efficient, and inexpensive sewage treatment methods applicable to complete, reliable treatment of sewage from housing subdivisions. This is one of the most acute and widespread problems in the sanitation field, judging from the number of requests for advice we have received. We are working on waste stabilization ponds and on anaerobic sewage treatment which seem to offer some promise as practical solutions to this problem. The situation is complicated by the reluctance of many health departments to approve discharge of wastes to open dry ditches even where the effluent is adequately treated by conventional yardsticks.

Determination of maximum tolerable concentrations of specific industrial wastes at municipal sewage treatment plants. The trend toward more extensive use of public sewers by industry in metropolitan areas is shifting to municipalities the burden of industrial wastes disposal. Availability of public sewerage service is often used by small communities to attract industry. Difficulty is often experienced at the sewage treatment plant because many industrial waste components, particularly heavy metals, may impair biological processes essential to sewage and sludge stabilization. As a result, sewage is inadequately treated and excessive organic loads are discharged to the stream. Because of inadequate knowledge of the toxic effects of such wastes, municipal authorities are unable to determine desirable limits of acceptability. Such knowledge is required if industrial use of municipal sewage facilities is to be allowed without abuse of the receiving stream.

* * *

WATER POLLUTION - PRACTICAL ASPECTS OF RESEARCH NEEDS

by

Ralph E. Fuhrman

The paper presented by Dr. McKee has brought us up-to-date on the scope and intensity of research needs in the field of water pollution. My treatment of the subject is to advert your attention to the problems of promoting, accomplishing and applying research as such and its results.

While it has been many years since Dr. Kettering's definition of research as "The study of what we can do when we can no longer continue to do what we are doing now," this plain statement is as good now as ever. In the rapid changes of the business world today, it deserves special emphasis. Perhaps there is more inspiration to Huxley's statement, "The future of the world lies in the hands of those who are able to carry the interpretations of nature a step further than their precedessors." It seems that the truth of such a statement could not have greater application than in current water pollution problems.

The often noted high degree of empiricism in waste-water treatment is simply another way of observing how practice has outstripped theory in many segments of knowledge in the field. At the same time, we must admit that great advances have come when theory reduces the gap between itself and practice. Fundamental as well as practical research both have a role to play and each is a distinct challenge to the other. It has been stated, "Whether a given research project deserves to be classified as basic or applied research must ultimately be a matter of personal opinion."(1) If this is accepted, it is certainly impossible to draw a sharp line between them.

With the full listing of desirable research projects presented by Dr. McKee, there is no need to single out certain projects and set these in a separate category, as no one can predict just where the results of fundamental research may be used. Perhaps the most positive statement that can be made is that such research is the frontier of knowledge in the field and this frontier will be advanced by the continuing study of the problems represented by these projects wherever such opportunities may be found. Those attending such a conference should certainly leave with not only a feeling that there is much to be done but that there are specific activities we should follow wherever and whenever possible. The fundamental research projects listed give sound guide lines for this effort.

The Need for Support

As to the promotion of specific research projects, it is a matter of fitting together facilities, men and money. Physical facilities are principally available in the Taft Engineering Center, universities offering sanitary engineering, and waste-water treatment plants serving industries and municipalities.

While money has been called the root of all evil, we must also admit that it is a strong motivation in the performance of research work. Properly guided research requires highly qualified professional direction which may seem costly but is actually economical when compared to the results achieved. Further, it usually requires to at least some degree the hiring of those who actually perform the work. This is usually the major cost of a research project.

The Need for Personnel

The men required are simply not hands but must be qualified to direct a project by: (1) determining the frontier of knowledge on a particular project by the review of work previously performed, (2) directing the project execution to make the greatest addition to this knowledge within the limitations of the project, (3) setting forth the actual conclusions and accomplishments to show clearly what has been done, what attempts at accomplishment have failed and why and, finally, to point the direction of further study in the subject area of the project.

We are all well aware of the bottleneck that has been apparent in a number of universities for the lack of men studying sanitary engineering. These men provide the natural reservoir for research workers in the field. While the obvious solution is to attract more men into the sanitary engineering field, no one has yet devised a way to bring this about. Recent efforts by the committee on Advancement of Sanitary Engineering are aimed in this direction. Likewise, recent efforts of the Public Health Service with its career film should be of some help. With the current economic adjustment, many of the more glamorous engineering callings have suffered reduced opportunities. Irrespective of how far these readjustments go, it appears that the work of civil and sanitary engineers is on the upgrade. It is interesting to note a conclusion reached by the Federal Reserve Bank of Philadelphia in its 1957 annual report. The Philadelphia "Fed" stated, "It is clear that houses, cars, and television sets are no longer 'needed' in the same sense as in the early postwar years. But schools, highways, water and sewage facilities, and missiles are 'needed.'" The hope of the civil engineer's increased usefulness is that he is concerned with structural design and construction of all these 'needs.' Further, he is the prime professional mover of highways and his brother or cousin, the sanitary engineer, is the prime professional mover in the water and water pollution fields. Perhaps there is further reason to feel this with the recent revelation of the radioactivity problems of space travel. It seems quite definite that the earth bound nature of man will predominate in the future and we should therefore increase rather than let down our provisions for safe and productive existence on this earth.

It is in this atmosphere that the following suggestions are given as minor additions to the project lists already in your hands. To be sure, these are not laboratory or pilot plant projects but nevertheless they have aims of equal or nearly equal importance.

The Metropolitan Environment

The impact of modern metropolitan area development is in itself one of great significance in man's environment. It is well to observe that the total population growth of the United States has not only been high but that it is taking place almost entirely in the Nation's 174 metropolitan areas. Communities originally established as suburban find themselves engulfed by the growing central city within the lifetime of the first residents rather than a period of generations. The 16,000 units of governments and 3,000 special districts in these metropolitan areas in themselves give a measure of the administrative problems and their complexities which usually include the collection and disposal of waste-water from all those living in the metropolitan area. From this experience of growth in these areas, it seems that the future will bring metropolitan area problems greater in size with a gradual increase in number as more cities grow to meet the Census Bureau's definition of a standard metropolitan area--an area containing at least 50,000 persons with population densities (by counties) exceeding 150 persons per square mile.

It is not important here whether we say the metropolitan area is a result of industrial development or that the industrial development is a result of metropolitan growth. Certainly they have gone hand in hand and the economic opportunities of industrial development have been a strong force. Supporting this view is that metropolitan areas seem to have a history beginning with the industrial revolution which started well over a century ago. The modern metropolitan area is the city that continues to grow in spite of its own and sometimes state boundaries. Socially and economically, these communities are one, but politically they are usually quite heterogeneous.

With the combination of metropolitan areas and industries, waste-water disposal problems are a natural consequence. While there are advocates of the combined treatment of waste-water from habitations and industries, many feel that industrial wastes should be treated separately. Certainly neither generalization is universally applicable. Some trade wastes are difficult or impossible to treat alone, yet when diluted with sanitary wastes, they respond to the usual treatment processes. The reverse can be true and, in such problems, appropriate research and investigation must be performed to find the answers to such questions.

Research Projects

While Dr. McKee's presentation has indicated many projects which are worthy of investigation, there are some I would like to add for your consideration. No attempt is made to comment on all of those listed, as their need is considered self-evident.

One could study metropolitan area complexes in connection with the collection and disposal of waste-water from multiple government areas. It combines engineering with economics and political science and is, therefore, quite different from the listed projects. The Metropolitan Authority is used frequently for the interception and disposal of waste-water from the area. An observation not entirely comforting to those in the water pollution field has been made in a recent book dealing with special districts.(2) In this volume the author decries the multiplicity of special district governments in the United States. While the number of 16,000 in itself would seem high enough for such a view, it must be remembered that each of these originated from a desire of the people in the district to create such a special district government. The author, a professor of political science, concludes that special districts are justified for schools, but feels other activities should be returned to local governments. Surely if a sanitary engineer makes such a survey, he would conclude that special district governments are justified for sanitary engineering activities as well as schools.

The fact that the metropolitan area scheme is being used more and more for waste-water disposal would in itself seem to justify it as a part of the American scene, but perhaps a study of this approach could either assure its continuation or point the way for improved and more economical approaches to water pollution control in metropolitan areas. Such a project would have important economic as well as engineering aspects. While this suggestion is limited to waste-water problems, it is interesting to note that actually every phase of environmental engineering has been approached through the metropolitan area technique.

Odor Control Research

Another problem, which is virtually as old as the water carried system, is that of odor control in sewers, pumping stations, and treatment plants. In the Nineteenth Century, the water carried system was evolved to remove domestic wastes from habitations. The results included elimination of heavy waste odors from living quarters as well as the removal of disease bacteria. Communities have extended this classic solution by conveying sewage to a downstream area for disposal, with or without treatment, sufficiently removed from population centers to escape numerous complaints. With the galloping growth of metropolitan areas, the vicinity of the treatment plant soon develops into a fringe area and is so encircled by residents that odor complaints arise irrespective of the direction of the wind. For many years it has been a matter of personal amazement that municipalities assume they acquire an air pollution right when a treatment plant is constructed. Surely odors confined to the plant grounds give no basis for complaint, but as soon as these escape to a public way or to neighboring property, troubles ranging from minor complaints to law suits may be anticipated.

Fundamental work on odor-causing compounds and odor intensity measurement was done at Harvard over 25 years ago.(3) Since that time much has been written about sources of odor at plants and how these may be controlled through plant cleanliness and chemical treatment. While cleanliness is essential, the fullest control of odors has been achieved by plant housing as done at the Owl's Head Plant in New York City with exhaust gases discharged through a stack after treatment with ozone. There has been recent publicity of the covering of a circular trickling filter at Sarasota, Florida using plastic covering on an aluminum frame for a filter cover. The results of this installation have not been publicized, but it seems safe to assume that a high degree of odor control will be achieved.

The place of research here could be a re-evaluation of the work previously cited and the extension of this work to find the degree of conformance with the characteristics of modern waste-water. With this information as a guide, the deodorization of these gases could be studied from the standpoint of the effect of various odor-destroying chemicals now available.

Experience to date seems to indicate that the most reliable control is the housing of plant units with treatment of the exhaust air. If this is really the case, it would be a great help to the field to have basic information on the economy of various designs. It should be noted that the cost of covering units is a surprisingly small proportion of the construction cost of a plant--if the housing is included in the original construction or if provisions are made in the original construction for such housing. The general adoption of reasonable odor control would go far toward removing the unsavory character of many waste-water treatment plants.

Higher Effluent Standards

Further beneficial research could be in the direction of higher degrees of waste-water treatment. Now a 90% removal of BOD is looked upon as "complete" treatment. This term is all right for use within our professional family, but outsiders become incensed when they realize that the treatment accomplished does not reach the perfection associated with the meaning of the word "complete."

Problems of the satisfactory disposal of treated hydrowastes (abwater) will become more intense in future years because the volumes of wastes to be treated will increase and the volume of a receiving stream will remain constant. If the receiving stream is also the community's water supply, the dilution water will necessarily diminish with the increased effluent discharge. With 95% removal of BOD, the organic load on the stream is 50% of that imposed by the effluent of a plant treating to the level of 90% removal. It seems that the future is certain to have a place for final treatments that would assure an effluent quality to meet these future restrictions. With the processes now established, stabilization ponds or intermittent sand filters may be relied upon to reduce BOD residuals to 5% or less. The development of processes that could be applied in locations where the large areas required for these methods are not available will surely have future application.

Such developments would certainly aid in efforts of water reclamation for reuse for many purposes other than drinking, cooking, and culinary purposes.

Research Agencies

The appendices to Dr. McKee's paper present a broad array of current and needed research in water and waste-water treatment. Both the fundamental and practical character of this work is certain to enhance our future knowledge of waste-water treatment. Patience is certainly a necessary virtue when either working directly on these projects or waiting for their results. However, when one visits the site of such research, he is likely to be struck by the busyness of the scene. Steady progress is being made on these problems and great credit is due to the research activities of several universities and the Taft Sanitary Engineering Center.

It is regretted that more research contributions are not made by large treatment works in the United States. Probably many of us know of specific examples of good work done in these plants, but it is often so related to local needs that it is not even offered to the technical press. Truly, much of this is applied rather than fundamental research, but the sharing of this information would be valuable to all in the field. Perhaps to an even greater degree these characteristics are inherent to research done by industry. Naturally many of these developments have a proprietary value and there is little incentive to share the results with competitors. Nevertheless, the exchange of such information could very well work to the benefit of all in the end.

Conclusion

In this atmosphere, it is well for each of us to review the activities of his own organization in an attempt to learn what further may be done to aid the overall research effort. From time to time the Federation of Sewage and Industrial Wastes Associations has been urged to sponsor research work. While the good of this cannot be categorically denied, it is well to consider the question of whether this is the greatest contribution the Federation could make to the effort. At the present time, the Federation provides perhaps the prime publication outlet for research papers, the monthly Journal, Sewage and Industrial Wastes. The Federation supplies this Journal to nearly 10,000 readers throughout the world to make this information available everywhere. This is done at a nominal cost to the member or subscriber. It is our belief that this is a substantial contribution to the overall research effort and its continuation is important to all of us. At the same time, we hope that it will be possible for the Federation to extend its influence in this field.

It is important that we continually watch the publication of research reports. Research work that does not find its way into printed literature remains hidden from most other research workers. For this reason, all research whether apparently productive or not at its conclusion should be reported so that the waste of effort and money of its repetition will be avoided. Even if work extends into lengthy reports or theses, the author should offer condensations of appropriate length for technical press publication as a minimum step toward sharing this information with other workers in the spirit of general cooperation with the overall research effort.

The appendices already referred to give in detail many specific projects which have been listed because each has been considered as a fruitful research activity. For its maximum value, such a list should be reviewed frequently for additions, deletions and changes. A great contribution can be made to the development of the water pollution control field by organizations as well as individuals in giving any possible assistance for the performance of such research work.

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TWO PAPERS ON AIR POLLUTION PROBLEMS

RESEARCH PROBLEMS IN AIR POLLUTION

by

Louis C. McCabe

Aside from public concern with the subject, the field of air pollution is a common meeting ground of such diverse professional interests as the physical and biological sciences, engineering, public health, economics, and the law. In one way or another these disciplines are concerned with man's environment - the changes that take place or are caused to take place in it, the effects of these changes and rules that may accelerate, delay or prevent such changes. Research and technology may embrace the complex and systematic approach to a Los Angeles smog problem or radioactive fallout; or may involve a less sophisticated elucidation, which I am assured is nevertheless the subject of a doctoral dissertation on file in the library of one of our learned universities, the effect of the prevailing winds on the location of pig pens in Will County, Illinois.

The explosion of world population, the expansion of communities and the growth of industry are accompanied by increases of air-borne wastes, new kinds of pollution or well-known contamination released in new places. In this country and abroad, widespread rebuilding of blighted or war devastated areas of cities has placed emphasis on air cleanliness as one of the good things of life. Better scientific information and better control equipment are bringing cleaner air nearer to realization.

In any air pollution situation the first requirement is to know what standards of air cleanliness are to be maintained. Why is it necessary or desirable to maintain these standards - for health reasons or to eliminate a nuisance? If smoke is the problem, is a change in the type of fuel necessary and what will it cost? If hydrocarbons and the oxides of nitrogen are responsible for eye irritation, crop damage and limited visibility, what are the effective concentrations and what are the feasible steps available to change the underlying chemical reactions? Are grab samples adequate for evaluation, or must there be instantaneous and continuous records? Are instruments available for measuring or must they be developed and standardized? If automobile and diesel exhausts are a significant cause of air pollution, whose responsibility is it to developthe control equipment, how much will it cost and when and where is it to be required?

The Effects of Air Pollution

Lack of scientific evidence that air pollution is injurious to health except in dramatic instances is not a satisfactory answer to those living in polluted atmospheres. While a health hazard need not be demonstrated to establish the need for air pollution control, the relation between air pollution and chronic disease must be found.

It has been said that "the role of air pollution on the health of a community (1) is so involved that the job of answering it seems almost insurmountable. Even from the standpoint of a relatively severe short-time exposure the answers do not come easily. . . Bearing in mind the difficulties in studying these effects of a severe short-time occurrence it is impossible to visualize the problem of evaluating the more nebulous effects of long-time exposure to much smaller amounts of contamination. In the latter case, one has much more opportunity to study the contamination itself...

"An answer to the question of the relation between air pollution and chronic disease must be found because of the many indications that a polluted atmosphere is not conducive to the best of health. . . It is obvious that a determination of the role of atmospheric pollution in affecting the general health of a population is going to require a tremendous amount of painstaking and costly research over a long period of time."

The economic effects of air pollution are more readily appraised than are health effects, and the response of animals and plants to certain contaminants can be observed and measured. The deleterious effects of air pollution on fabrics, metals and buildings represent a significant loss in every metropolitan area, and need a more careful study than has been done heretofore. There is growing concern in some congested areas about the effects of air pollution on the operation of airplanes and ground transportation.

The Extent of Air Pollution

Topographic and meteorological factors are important in any scheme of air pollution control. If cities could be planned with this in mind there would be less objectionable air contamination but this is rarely possible. Favorable weather conditions may permit the release of air pollutants in one area which cannot be tolerated under less favorable conditions in another place. Topography has an important bearing on whether wastes discharged to the atmosphere will accumulate in objectionable quantities. Valleys crowded with industrial activity are noted for their smogs and were it not for the advantages of transportation and water supply, they would be avoided as industrial sites. Perhaps the opportunity for avoiding the damaging effects of air pollution on metropolitan development should be the subject of a study directed to the attention to land use specialists and planning groups.

Air pollution does not respect political boundaries, and the enactment of statutes, rules, regulations and codes by a metropolis are of no effect if the air contaminants of a neighboring community, borne by the vagaries of the wind, or confined by topographical and meteorological conditions are deployed over an otherwise regulated community. It has become increasingly evident that the control and abatement of air pollution is not a narrow local problem, but one which calls for county-wide, state-wide or interstate regulation and cooperation.

The States of California, Delaware, Florida, Kentucky, Massachusetts, New Jersey, New York, Oregon and Washington have enacted legislation seeking to control air pollution. Regulations promulgated under such legislation place the emphasis on using fuels efficiently so as to avoid the production of smoke and fumes, and on the prevention of the emission of solids, gases, liquids and vapors by requiring that equipment designed to accomplish this be installed and operated efficiently, rather than by purely punitive measures or the imposition of fines. The elimination of the causes of air contamination rather than the abatement of a nuisance appears to be the goal of present day legislation.

The Limits of Air Pollution

In Los Angeles (2) a medical and scientific group recommended allowable concentrations for a small number of specific compounds in the community atmosphere. Limits were established for oxides of nitrogen, ozone, sulfur dioxide, and carbon monoxide. These limits in parts per million of air were adopted and have been in force since 1955. The warning level has been reached by ozone and approached by the oxides of nitrogen during heavy smogs.

This is not the first attempt to set limits for air pollution, however. Swain (3), in 1910, suggested an hourly average of 1 p.p.m. for sulfur dioxide at the ground as the maximum permissible discharge for smelters in farming areas. About 20 years ago, the Trail smelter (4) set up an operating regime to prevent SO_2 damage to crops in the Columbia River Valley.

The oldest and best known effort to apply an objective measurement to air pollution was made by Maximilan Ringelmann (5) about the turn of the century. The chart which bears his name was introduced into the United States in 1908 and is the basis of smoke evaluation in many ordinances in this country. It has served very well as a reference for establishing smoke density or training individuals in the observation of black smoke.

These examples represent some of the attempts at exact definition of air pollution. In fact, the Los Angeles maximum allowables are admittedly experimental and the Ringelmann chart has its limitations. It may be concluded that like many other facets of air pollution, if definition were easy it would have been agreed upon long before now. As research progresses, there will be more exact standards of air purity but at present it is defined with considerable variety and some trepidation.

Specific Areas of Research Needs

The Public Health Service, the Los Angeles County Air Pollution Control District, and other organizations have made intensive surveys of pollution and the associated meteorological conditions. The point has not been reached, however, where it is possible to extrapolate the detailed conclusions to other cities. The numerous micrometeorological and microclimatological surveys made for other purposes, if available, would be extremely useful in evaluating the diffusion of effluents in many cities. Again the question arises whether the policy of secrecy or overclassification of scientific information is in our best interest.

More information is needed on the factors affecting air movement in different types of localities and on the interaction and fate of pollutants, especially at times of temperature inversion and fog when the concentration of pollutants is likely to be greatest. It is important that there be a thorough study of local meteorological conditions in planning for the abatement of pollution and for its prevention in the planning of new industrial and community development. As population grows, communities and industry must grow to meet people's needs. A satisfactory solution to the air pollution is not in the denial of space for growth but in informed site selection and effective control of air-borne wastes at the source.

Typical programs, instruments and procedures should be developed for communities of varying size and budget who are setting up air pollution programs. Much can be accomplished in the reduction of air pollution using simple instruments and methods for the measurement of dustfall, smoke and the common gaseous contaminants.

Data should continue to be developed on the subject of maximum allowable concentration of pollutants in the ambient air.

Morbidity and mortality rate studies for chronic bronchitis and primary lung cancer need to be made where information on the significant variables is available.

Many complex air pollution problems now come before the Courts for resolution. There is need for study and research by the legal profession of the means of presenting the scientific facts to the jurist.

Public Law 159, 84th Congress (July 14, 1955) authorizes the Surgeon General of the Public Health Service to recommend and conduct research, studies and investigations to reduce or eliminate air pollution, in cooperation with other federal agencies, states and local governments, air pollution control agencies and other public and private agencies. Enforcement is the responsibility of the states and local communities.

The problem of air pollution arising within one state and crossing its boundaries of a neighboring state are properly subjects for interstate agreement by compact between two or more contracting states.

The recent state statutes generally provide for research in the field of air pollution control, for dissemination of the general public, enforcement authorities, and public and private agencies, of information and knowledge gained from such research, and for the use of conference, conciliation and persuasion to eliminate the sources or causes of air pollution prior to exercise of the police power to achieve that purpose.

The authority of municipalities to enforce local statutes designed to abate smoke pollution as a nuisance, and the constitutionality of such statutes have been upheld by the Courts on numerous occasions where the application of such statutes and the regulations promulgated thereunder has been reasonable.

It may be concluded that the legal pattern for air pollution control has been set and that research will be accomplished and coordinated in the field of public health.

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FUTURE PROBLEMS IN AIR POLLUTION RESEARCH

by

Leslie A. Chambers

For a long time to come the exploding population of the earth will be forced to find means of adaptation to the planetary environment - in spite of projected excursions into outer space. Perhaps the science fiction dreams of colonization in other parts of the galaxy will be realized some day in the distant future, but for all of us and our children's children there will be only the large but certainly not infinite global resources of earth, air, water, and fire to divide among the growing numbers of coinhabitants, to use, and to conserve.

Of these four "elements" of the ancient mystics it has been easy to recognize the limitations in mineral resources taken from the earth, and of water supplies pure enough for human use. When the impending insufficiency of fresh water became apparent we were forced to recognize the need to tap energy sources such as the atom and the sun to supplement the vanishing fossil fuels. But the air we breathe, presumably because of the illusion of boundless volume afforded by its transparency, is still difficult to consider as a resource which can be exhausted or rendered unpleasant to live in by the very acts of living. Only recently have a few communities experienced difficulty in adapting themselves to the volumes of air available to them under occasional circumstances of limited wind movement.

In two or three cases the communal quota of air has been so filled by the products of municipal katabolism that it has killed. In a small number of other areas, as in Los Angeles, the pollution has caused chronic recurrences of personal discomfort, has limited agricultural production of foodstuffs, and has violated aesthetic sensibilities.

Such events have been, and of course are, of great importance to the affected communities; but they have much greater significance as advance predictors of things to come in these and other metropolitan areas if no action be taken to avoid overuse of the air supplies during periods of minimal flow. What has affected Los Angeles and a few other cities in recent years will almost certainly produce similar difficulties in many other cities at some stage in metropolitan growth. In this sense, at least, the problems still unsolved in these places will continue to be the research objectives for some time in the immediate future. In other words it can be anticipated that necessity will force the unsolved problems of the present to pattern air pollution research in this country next year and the next, and to a diminishing degree (proportional to the annual effort) through the following decade or more.

This assumption makes the task of defining areas of needed information relatively simple. The following tabulation of present problems which await future solution is a composite of the convictions of a number of informed people with whom the question posed by this conference has been discussed. It is probably significant that each one suggested essentially the same listing, although there was no general agreement as to the relative importance of the items.

The Chemistry of Air Pollution Systems

While it has been about seven years since establishment by Haagen-Smit and others of the general principle of photochemically induced interactions among primary atmospheric pollutants, the extraordinary complexity of the dynamic photochemical systems affecting Los Angeles and other cities is only now being fully realized. Substances causing eye irritation, accumulations of ozone, damage to vegetation, and possible physiologic damage in man appear to be labile, transitory constituents of the ever-changing system, and have therefore proved difficult to measure or even identify. Their existence appears to depend on the photochemical formation of free radicals, if indeed certain types of free radicals are not responsible for the observed and suspected effects. Since the existence of free radicals is essentially co-terminal with the activating solar energy, capture and analysis apart from the continuously activated system have not been accomplished nor even seriously attempted.

Of course, in existing situations it is possible to recognize the primary reactants involved in the chains of reaction; in Los Angeles the elimination of oxides of nitrogen and of organic vapors, especially the unsaturated compounds, would effectively inhibit the formation of the suspected labile intermediate compounds. But it has proved difficult to ban by fiat, as in the case of incinerator products, either of these two classes of reactants as a whole. It is my opinion that, in the long run, the practicable form for control of such reaction products will prove to consist of a very selective elimination of those species of primary compounds determined to dominate the identified reaction chains. For example, if it turns out that the total loss of hydrocarbons to the atmosphere, from all the widely scattered sources, consists largely of saturated compounds with little or no significance in the reaction, then it would probably be less expensive and more practicable for the community to expend its tax monies and effort on control of the relatively few highly reactive species. Much difficult and exacting research will have to be done before the essentials of the photochemical mechanisms are sufficiently understood to make such selective control predictably effective.

The Chemistry of Sulfur Compounds

While the importance of SO_2 and SO_3 in the London disaster of 1952 has been inferred, and the role of these products of the combustion of sulfur containing fuels in acute air pollution episodes elsewhere has been suggested often, there is still a considerable area of missing information as to what really happens to sulfur compounds in photochemically activated atmospheric systems. Johnstone and his associates are contributing valuable experimental evidence of the rates of formation SO_3 from SO_2 in the presence of moisture and of catalytic particles, and Amdur has produced evidence of enhancement of SO_2 toxicity by the presence of NaCl aerosols of small average particle size. But there are numerous theoretically possible interactions among SO_2 and the assorted organic and inorganic free radicals believed to form in the polluted air during irradiation. Malodorous and potentially toxic intermediates are possibilities. This group of reactions does not appear to have received very much attention although sulfurous combustion products are usually among the first pollutants suspected in communities feeling the effects of atmospheric contamination.

Physiologic Effects of Aerosols in Atmospheric Reactions

Doctor Amdur's work, referred to above, has drawn sharp attention to the possibility that some species of aerosols influence the toxicity of some kinds of gaseous pollutants. This phenomenon has been suggested previously and in reality is supported by scattered evidence from a number of sources.

Another role of aerosols in the air polluting system has been suggested on theoretical grounds and is receiving experimental support as the result of the work of Calvert and his associates at Ohio State. There is a possibility that specific kinds of air-borne particles act catalytically in the photochemical system to a significant degree. Intervention of such an accelerative process could lead to error in estimates of the overall oxidative or other reactive capabilities of air-borne mixtures. Determination of the kinds and degrees of interaction among gases and particles will require skill, new techniques and much high quality work. It could lead to much improved accuracy in the selective control of significant pollution sources.

Physiologic and Toxicologic Effects of Specific Pollutants

It is unfortunately true that very little definitive knowledge of the effects of most of the substances known to be present in the air of our cities is available. Prolonged dosages at low levels of concentration of highly reactive oxidants, free radicals, and condensation products of the photochemical reactions of organic compounds, are strongly suspect in relation to various chronic and acute diseases of the respiratory system among city dwellers. Which, if any, are culpable? At what levels of concentration do they cease to be troublesome over long periods of exposure? Do they produce, or predispose to, carcinomas of the lung and other sites? Does long exposure to any of them at some level of concentration affect longevity, work efficiency, or general well being of men, women, and children? Do any of them specifically or in combination with other circumstances, adversely affect respiratory, or other restrictive systematic impairments?

All of these questions, and many others, need answers to provide bases for general or specific control standards and, to give the public the assurance it should have that control actions may reasonably be expected to protect them against dangers presently definable as vague conditional concepts.

Development of Procedures and Instruments for Analysis

Our understanding of atmospheric reactions and their products, effective monitoring of pollutant levels, and making useful pollution surveys, will be limited for a long time in the future by the tools available. We measure and record "oxidants" and "sulfur dioxide", "oxides of nitrogen", "hydrocarbons", and many other significant properties of polluted air by methods which have limited specificity in most cases, and in others (e.g., "hydrocarbons") actually are incapable of estimating many species of the general class.

Furthermore, most of the instrumental methods for monitoring and survey are so costly and complex as to preclude use by any but the most severely affected communities. Instrumentation and analytical methods for air pollution work need to be made inexpensive, simple, direct, and specific in principle and in operation.

In at least one area meterologic instrumentation and methodology have proved to be beyond reach of any local jurisdiction: surface weather phenomena can be analyzed effectively, but existing methods for measuring vertical air movements below the inversion base would be too costly to be utilized. It will be essential, in regional zoning plans, that patterns of pollution movement in all three dimensions of the air reservoir be established by new and cheaper methods.

Part of the cost problem related to pollution surveys may be attributable to a tendency to "keep up with the Joneses." It is reasonably suspected that, of the numerous measurements habitually incorporated into air pollution surveys, only a few (perhaps one or two) would give information fully as useful as that obtained by all them together in any given local situation. One of the most pressing immediate needs is the provision of bases for selection of one, two, or three simple, direct indices of pollution in relation to identifiable patterns of pollution source.

Air Pollution Problems for Future Research

The five problem areas certainly could be extended in terms of engineering control of sources of pollution. As technologic changes occur in manufacturing processes, transportation and commerce, a continual procession of new abatement techniques will be demanded and developed. Engineering problems never will be quite solved.

Our review leads naturally into much less certain speculation on what may constitute the major air pollution concerns of the next half century. It is none too soon to look so far ahead since, even in these days of accelerated scientific advance, any change in practices related to the public health seems to require ten to thirty years of exploration, reconfirmation, and public education prior to implementation. On the other hand the pace and inventiveness of modern scientific effort militate against clairvoyance. The following suggestions are predicated on knowledge of a few things taking form at present which seem destined to affect the air supply, or improve our capability for cleansing it.

1. Pollution by Radioactive Materials

There is a considerable body of informed opinion insisting that the air-borne products of nuclear fission and fusion processes are endangering the health of the present and future generations. Nothing foreseeable will prevent the continued exploitation, on an expanding scale, of atomic energy whether for peaceful or military purposes. Therefore it appears inevitable that both local and world wide problems of pollution by radioactive by-products will increase in frequency and intensity.

2. Meteorological Control of Local Air Pollution

Significant strides in the direction of long-range weather prediction have been made during the past twenty years, and some progress toward local modifications of meteorological phenomena has been reported. Our imminent capability for satellite observation of air movements, and the availability of almost unlimited energy from nuclear processes, make it worthwhile to consider modification of regional meteorology as a means of assuring more adequate local air movement. It should not be forgotten, in speculation on such possibilities, that the movements of water in the oceans are often basic factors in weather patterns. In imagination, at least, the detailed oceanographic and meteorologic studies initiated as part of the IGY program, could be of immense usefulness in air pollution control in the distant future.

3. The Effects of Air Pollution on World Climate

One of the questions on which the IGY program is seeking data relates to the possibility of gradual and recent increases in the concentration of CO_2 in the world's atmosphere. Some evidence has been advanced to the effect that combustion processes are adding CO_2 so rapidly as to cause accumulation in spite of the water reservoirs with which it must be in equilibrium. If this is indeed the case, it is predictable that the rate of increase in CO_2 will accelerate as human activities surge to successively higher levels. A significant change in CO_2 level in the air could, in theory, produce profound effects on world climate. Some form of CO_2 monitoring on a world wide basis might well be continued as a means of determining the time at which air pollution will have become planetary in its effects.

4. Jurisdictional Problems in Air Pollution Control

Many of the foregoing problem areas imply extension of air pollution study and control beyond local, State, and national jurisdictions. Already, in a few regional situations, there has appeared need for the establishment of acceptable procedural and survey patterns which will permit a variety of authorities to act jointly without undue violence to the autonomy of the participants. While preparation for concerted action among affected governmental units does not fall into the scientific research category, it will be essential to the effective application of technologic principles now known and to be developed.

Summary

Those of us engaged in air pollution control activities are generally not encouraged to look too far into the future; the demands of the present take precedence, and the agencies with which we are associated have no capability in law or in precedent to plan actions designed to be effective more than two or three budget years in advance.

Nevertheless, it must be apparent, whenever we do project the developing trends of community sanitation into the future, that the problems we face are increasing in some exponential relationship to national and world populations. Almost all the environmental factors demanding attention are of two sorts: (a) those involving competition for finite amounts of the materials required for human existence, and (b) those resulting from accumulation of by-products of the human utilization of such substances. Thus air, water, and basic nutritional, industrial, transport, and energy requirements become the foci of almost all efforts to maintain health, reasonable living standards and some comfort in the face of an exploding population. Sooner or later health agencies will have to face the fact that 600,000,000 people cannot live well in the waste products of resources capable of sustaining half of that number.

I therefore suggest that the air pollution problem of the remote (?) future will have to find its solution, in common with other problems of living together, in some form of population control. Perhaps we will have the courage and perspicacity to tackle the job before it is too late. If not, nature has a habit of imposing her own limiting measures usually in a manner antithetical to the philosophies of public health.

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TWO PAPERS ON FOOD TECHNOLOGY PROBLEMS

RESEARCH PROBLEMS IN FOOD TECHNOLOGY

by

Emil M. Mrak

Food Technology is a relatively new field involving the application of various natural sciences and of engineering to the handling, processing and distribution of foods. The application of these sciences from the point of view of a food technologist is a recent and important development, resulting to a large extent from great changes occurring in the eating habits of the American people.

This country developed as a farming community with the result that most food preservation was done in the home. As time went on, however, there was a movement of people to the city with resultant increase in the production and distribution of processed foods. Naturally, changes in food habits accompanied both this movement of people and the introduction of processed foods. These changes have been most dramatic since the last war. Today progressive food processors and distributors are attempting to determine consumer desires and satisfy these requirements in the type and variety of foods distributed. Food processing and distribution is about an 80 billion dollar industry, the largest in this country.

The efforts of this industry have resulted in a tremendous variety of processed foods, a better and easier life, and a higher standard of living. At the same time this development has created a fantastic number of scientific problems and need for research by all agencies including government and state as well as industry. The need is especially great for support for fundamental work that will build up a stockpile of information on foods. The U.S. Public Health Service should have a genuine interest in developing and sponsoring such research if it is at all interested in the welfare of man. Most certainly the welfare of the individual is dependent to a large extent on the type, amount, quality, and condition of food he eats.

Consumer Acceptance Factors

The processor today is well aware that he must consider consumer acceptance and the factors of color, flavor, texture, convenience, stability, asthetics, nutrition and safety all of which influence the consumer. In order to maintain or obtain the desired color, it is at times necessary to use particular processes or certain chemicals. Yet, the color of many items, such as canned beans, peas and spinach, are far from satisfactory. There is a great need for fundamental work on the nature of natural colors and the influence of various processing treatments on them.

Flavor retention has been a real problem. Very intensive studies are being conducted on the nature of flavor and effects of various processes and storage conditions on the retention of flavor. Synthetic flavors are being used more and more. It is a well established fact that flavor is more important to the consumer today than ever before. Yet our knowledge of flavor chemistry and what happens to flavor during processing and storage is very feeble. Texture and rheological characteristics are extremely important insofar as acceptance or rejection of foods are concerned. This applies to many foods, particularly bread and certain dairy products. Still we are in the dark as to why bread stales, or texture and rheological characteristics of other foods change. It is necessary to study very intensively the fundamental aspects of these physical properties and to relate them to processing techniques, storage, acceptance, spoilage and even nutritive value.

In recent years convenience has received more attention than any other single consumer factor. This is well manifested by the great number of convenience foods that have been introduced during the past few years. These have involved the use of a great variety of chemicals, the mixing of various food components and the use of new processing techniques. While these very convenient products have been studied from the standpoint of consumer convenience and acceptance, an enormous amount of work remains to be done on the stability, safety, nutritional properties and other factors relating to these products.

Stability of Foods

Stability or shelf life is an extremely important factor in all foods for practically none can be considered unperishable if held under adverse temperature conditions. Deteriorative changes resulting in loss in flavor, color, texture and above all nutritive value occur very commonly during storage. Food conferences are now being held at the state level to encourage better nutrition. Much is said about variety and proper foods but thus far I have not heard a single word about storage deterioration and its possible relation to adequate nutrition. So much needs to be done on storage deterioration that it is difficult to know where to start. In addition to the possible changes already mentioned, rancidity and the "browning", "staling" and "fish oil protein" reactions are far from solved. Only now are we starting to obtain an idea of the mechanisms involved in the action of antioxidants. We don't even understand the other deteriorative reactions and of course have no satisfactory means of control.

These deteriorative changes are important not only from the standpoint of nutrition and acceptability but, possibly, safety. There is some evidence to show that the chemical products resulting from deteriorative changes can be harmful. Some of the products of deterioration may affect appetite. The need for work in this area is apparent.

The asthetic values of foods are of course very important to the consumer. If the consumer is aware of rodent or insect contamination or the presence of filth or dirt it is quite likely he will not consume the food. While insect contamination as such would probably not harm a person it is repugnant. For control it has been necessary to use chemical fumigants and it appears that these are safe. Nevertheless, there should be sufficient evidence to support the view that they are safe.

Nutritional Values of Food

The nutritional value of foods is of course of prime importance. A great many studies have been conducted on the retention of vitamins, mineral constituents and so forth, by foods during processing and distribution. Yet, the entire story is far from complete and we need a great deal of research along these lines. Most likely our foods are the safest produced in the world. However, we should be engaged continuously in building up a stockpile of scientific information relating to food safety.

Thus far I have only mentioned factors of importance to the consumer, and those which are considered by the processor in his attempt to produce foods that appeal to the consumer. However there are processes and handling procedures that affect these foods adversely. Because of this there is a real need for both fundamental and applied research programs on a very extensive and intensive scale. Enormous changes may take place during processing, but unfortunately, in most cases we know extremely little about these changes.

We are marketing large quantities of fresh produce but little if any attention is given to the edibility of these products or how they may be improved from the standpoint of the consumer. We should learn more about the nutritional value and acceptability of fresh produce as it is sold in the market. There is a general belief among consumers that fresh products are far superior to those that are canned, frozen, or dried; yet we know that fresh produce can deteriorate very rapidly in acceptability and nutritive value. We may learn that, on the whole, processed foods have better vitamin retention than the fresh - because of improper harvesting, distribution and handling procedures. Processors must be very careful about chemicals residues, insect fragments etc. but relatively little attention is given to these factors insofar as fresh produce is concerned. Because of this there is a need for some extensive studies on the acceptability, nutrition values and general quality of fresh produce.

Great changes are taking place in canning procedures. The so-called short high temperature procedure is receiving more consideration because of increased case yields, faster operation, and better color and flavor. However, there needs to be considerable study of the relation of this type of treatment to storage stability, nutritional value, and acceptability of the product. Without doubt it has merit, and will prove to be a very excellent process when all factors are studied.

While dehydration is still a very important procedure for food preservation, the "browning reaction" occurs very commonly in dried products. This reaction received considerable attention during the war, but very little work is being done on it now. Fundamental work in this area should be emphasized.

A great deal has been said about the production of fish meal for use in food-deficient nations. Only recently have we at California obtained any real inkling as to what is involved in the so-called "fish protein oil" reaction. It is rather astounding that we have long produced fish meal, that undergoes such drastic deteriorative changes, without some curious scientist looking into the mechanism of the process. We are starting to understand this process and now know that it can be retarded markedly by use of a specific antioxidant; we do not yet use this treatment, because we do not know whether it is needed or whether it would be safe to use.

Insects and rodents commonly infest dried fruits; the various control procedures used involve fumigants, special baits etc. There is a need for new control materials and for a careful screening of these materials for safety and effect on food before they are used.

Low Temperature Preservation

The production of frozen foods, particularly pre-cooked or partially cooked, has increased at a fantastic rate. Items such as meat, chicken and fish pies, fish sticks, chow mein, stuffed poultry and a whole galaxy of other such foods were hardly known a few years back. The production of these items has increased at such a rate that it is improbable adequate studies of the changes in microflora have been made. Some of us have wondered if the Public Health Service might not have been remiss in failing to conduct and promote extensive studies in this area. Frozen foods undergo deteriorative processes that often result in undesirable changes in flavor, texture, appearance etc. Relatively little is known about some of these changes, yet they are so important to the health and welfare of the consumer.

While on the subject of frozen foods some mention should be made of chilled foods, particularly cut-up chicken. The use of antibiotics to extend the shelf life of chilled cut-up poultry is a recent innovation. This was permitted on the basis of considerable laboratory data even though field tests to determine whether or not a build-up of resistant forms might occur was not done until the material was in commercial use. A great deal more needs to be done in this area for we are aware of specific cases where the build-up of psychrophyllic spoilage organisms has occurred.

Concentration of foods by use of vacuum at relatively low temperatures is now a common processing procedure and a good one. However, a great deal remains to be learned about the effect of this process on enzymes, chemical changes, microbial survival and vitamin retention.

A great deal has been said about radiation and millions of dollars have been spent on researches in this field. A great deal more must be done with respect to off flavor development, resistant strains of microorganisms (particularly botulinus), destruction of vitamins and amino acids, and safety.

There is a good deal of circumstantial evidence to indicate the fairly common occurrence of food born infections, but insofar as I know, the amount of work being done in this field is limited. How extensive is Salmonellosis? Are staphlococcus infections increasing? The California Public Health reports show a thorough understanding of the causes of these infections with the development of control procedures be better than prescribing drugs after infection?

Today more than ever before we are using chemicals in our foods. This is as it should be, for the safe and intelligent use of chemicals enables the development of new and better foods. Naturally care must be taken to be certain that food additives are safe. There is much to do in this area; for example stearates are supposed to cause an increase in size of rat livers. Just what does this mean? Is it important?

Food Packaging Factors

There was a time when most of our foods were sold in bulk in the small corner grocery stores. Today most of our foods are packaged. More and more are being packaged in newer and better packaging materials. Some of these materials come in direct contact with the foods whereas others do not. The Food and Drug

Administration insists on the use of safe materials and maintains a careful vigilance for new ones. Nevertheless there is a need for the development of standard and adequate testing procedures and for information relating to the possible reaction of packaging components with food components.

The Food Protection Committee of the National Research Council is only now trying to develop a list of the important packaging constituents. This study involves materials in use for a long time, such as wood, metal, paper and glass as well as new plastic materials. These all contain a number of components - some of which may be extracted by certain foods and not by others. Details of these behaviors are important and certainly should be studied. The Committee, however, does not concern itself with the many new types of plastic containers used in the home and it appears that no one does. Are they all safe - one wonders.

The food industries are mechanizing as rapidly as possible, even though a complete understanding of the effect of these changes on acceptance, nutritive value and storage characteristics are not clear. For example the bulk handling of cling peaches from the farm is almost a reality, yet we do not know what effect such handling procedures will have on the fruit. Last year we tried transporting peaches in water in polyethelene containers. Those held in the containers 6 hours had a very low acceptability because of off flavors.

Food Research Problems

The milking machine is another example. When improperly used it injures the tissues and thereby encourages the growth of mastitis organisms. To cope with this infection the farmers apply penicillin, with the result that milk is commonly contaminated with penicillin. We have studied air pollution in an almost extravagant manner and water and waste disposal inadequately. Food has received very little consideration from the Public Health Service yet it is an extremely important component of our every day environment.

Food should be studied from the full spectrum point of view - that is, from the time the seed is planted, the egg is laid, or the animal is born, until the time it is consumed. There are many things that may happen during these steps, from the peach orchard to the consumer, for example, wherein one factor may influence the other so that none can be overlooked. In the end they all are of importance to the consumer. If we are to give the consumer canned peaches with the lighest vitamin content, best flavor and color that are safe, then it is important to know what happens between the orchard or processing plant and consumer.

Today there is a trend toward the artificial ripening of fruits in order to prevent losses between farm and the processing plant. This appears to be a very desirable procedure. We should, however, undertake research to learn what this procedure may do to the nutritional value, flavor, color, texture and storage stability of this fruit. We should know what it will do to consumer acceptance, and whether or not this type of treatment will adversely effect the product and the consumer. It is quite possible that some treatment during processing will adversely influence the storage of the product with a loss in nutritional value, or color, or perhaps even the production of compounds resulting from deterioration that may adversely influence the consumer. The point of view of the importance of foods to the consumer has for some reason, been overlooked by the Public Health Service. Perhaps this problem is less glamorous than some of the work underway, although these factors are equally if not more important. Truly there is a need for emphasis on the food component of mans environment.

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PROBLEMS IN FOOD TECHNOLOGY RESEARCH

by

Walter D. Tiedeman

Any discussion of the age-long problem of "Man vs Environment" should be far reaching. We all are familiar with the historical pattern of technological advances on the one hand raising man up and of catastrophe, disease, famine, and war on the other hand tending to destroy him. Let us take an equivalently long look into the future by projecting the established line to see where it is leading us.

Before presenting the research problems in food technology of today and of the coming century, let us consider briefly what happens if we continue current trends "ad infinitum." If we maintain the present controls over all the factors tending to curb population and make the fullest use and perhaps expand somewhat our current abilities to control environment, thus further extending life expectancy, how much longer will it be possible to find a favorable place in the sun for each of the world's multitudinous inhabitants? It appears that too many people, each demanding a share of the available good food, air, and water is more than likely to be the final research problem in our effort to help man conquer environment. For the skeptic we call attention to the current increase of at least 3 million per year in the population of the United States. It is not our intention to suggest that we desist in our effort to swing the balance in this struggle in man's favor, but simply to plead that we take the broad look as well as the long look ahead and encourage contemporary workers in the fields such as the social sciences to develop reasonable new population curbs to take the place of nature's harsh ones of disease, famine, and war which otherwise surely must be brought into play in one way or another.

Research Accomplishments

We are all proud of the accomplishments of our agriculturists in making 2 ears of corn grow where only one grew before. As a result, we depend upon further research to make 4 ears grow where only 2 grew before, and so on; but, at the same time, our most fertile lands are being occupied by factories or rural home developments, or are zoned and taxed out of use as food producing areas. Is it better to maintain a balanced economy or eventually to become dependent upon distant and perhaps alien sources for the food we eat? This is a long way off but within the realm of possibility. Unless something is done to conserve productive lands our No. 1 research project in this field should be a study of how to grow more and more food on less and less land, including some of the rocky crags which will remain after the desirable low-lands are covered with factories and homes.

Much research work has been done in the field of animal nutrition but proportionately little in human nutrition. As a nation with surplus food our major problem has been to control obesity rather than generally to fight malnutrition. With the possibility of a future food shortage economy, it would be advisable to seek the answer by research to such questions as that raised during the shortages of World War II: whether it might be good economy, without risking nutritional health hazards, to feed grains directly to people rather than to animals to produce meat for people. A study of the specific applications to humans of some of the important principles of nutrition learned in the feeding of domestic animals also should provide valuable information to help man conquer his environment. Sooner or later, perhaps very much later, the problem will shift from that of too much to too little food.

Practically all of the processes of preserving foods by the application of heat have been developed to the point at which no known important health hazard remains. In this category include pasteurization, so-called sterilization, and dehydration. Pasteurization has been applied to a number of foods although milk remains as the classic example. The point has been reached at which the public is adequately protected against common milk-borne diseases of bacterial origin. It still would be helpful as a matter of basic scientific interest to more completely develop the curves showing the effect of heat on at least the more heat resistant of the common pathogens in milk and some other foods. Furthermore studies are needed of the possible presence of viruses in milk perhaps in tissue and the effect of pasteurization thereon.

Commercial canners have solved the serious problems of the spread of botulism through canned goods and much research has resulted in improvement in the taste and nutritional properties of their product. Because customers are very conscious of these advances and they pay off in dollars, it appears that adequate development will result from this self-sponsored industry control. This is characteristic of free American enterprise at work. It is heartily recommended that, even though considerable basic research sponsored by the Federal Government may be necessary, the policy be continued of turning the results over promptly to free enterprise to further develop for the benefit of all of the people.

New Needs in Research

In the field of dehydration there was considerable concern during World War II over the presence of Salmonella in dehydrated eggs. Egg washing before cracking was found to be ineffective but research in the Department of Agriculture led to the development of a moderate pasteurization sufficient to destroy Salmonella without damaging the physical properties of the food. If similar problems arise they are worthy of study and again we suggest a study of the presence of viruses. If they are present we are interested in knowing whether they multiply or simply survive and how they can be effectively destroyed.

In the preservation of foods by holding them at low temperatures we find somewhat decreased dependence upon lengthy storage (at temperatures between 32 and 50 degrees Fahrenheit) and increasing use of quick-freezing (with storage at about 0°F). In fact, the much heralded hot blue-plate dinners from coin-operated vending machines are only "just around the corner." The problems to be solved are (1) to heat the foods rapidly and uniformly enough, and (2) to supply some unheated items such as a salad along with heated ones. Of course this development is in the realm of commerce, but if it should not prove to be profitable and if industry dropped this effort there are other practical applications in emergency feeding that still would make a study of this problem worthwhile. The availability of such dinners from manually operated equipment appears to be an admirable solution for the feeding problem of the small hospital, and perhaps for some that are not so small but in which (due to warming methods) all food smells and tastes alike. Good sanitation must be practiced in the preparation of frozen foods, whether cooked on plates or packaged raw, as bacteria have been found to survive therein for long periods.

Sterilization by Radiation

The possibility of the commercial sterilization of foods by radiation has been the subject of much ballyhoo in feature articles. Continued research in this field is highly desirable. However, we must look for possible immediate practical results by partial treatment - such as the exposure of pork to radiation sufficient only to prevent *Trichinella spiralis* from reproducing. It would be necessary to keep meat so treated under refrigeration, but danger of the spread of trichnosis (if it were undercooked) would be gone. Although the deleterious effects of the sterilization of foods by gamma radiation on flavor, color, and odor has been well demonstrated, further advantages of partial treatment, such as in controlling insect infestations, may be demonstrated. Some research workers feel that success in food sterilization without excessive damage to quality may come through the instantaneous discharge of still higher-speed electrons than have been commonly used. There is enough glamor connected with studies in this field to attract workers without much urging, and considerable research is under way.

One of the radiation problems possibly resulting from fall-out of radioactive dust is the finding of strontium 90 in cows' milk. It is possible, but currently not likely, for this to reach serious proportions and thus endanger one of our most useful food supplies. More generally study is needed of possible effects of radioactive fall-out on food supplies of the future.

Great progress in the development of chemical products in recent years has carried with it a marked increase in chemicals available for addition to foods directly or indirectly as well as an increased interest in the possible use of such chemicals. Perhaps the most recent and greatest interest is in the use of antibiotics. This is not as unnatural as it would seem, when we consider that research workers have found natural antibiotics in such foods as bananas. The commercial use of chlortetracycline in preserving chicken has been approved. Such approval is based on the assumption that the chicken will be cooked before eating and on laboratory demonstration that any of the heating methods commonly employed in preparing chicken may be depended upon to destroy any residual antibiotic. Many other uses are in the experimental stage.

Many problems are presented by the use of chemical additives, starting with poisonous spray residues on grain fed to cattle, or on fruits and vegetables for human consumption. Official regulatory agencies are aware of this problem and are conducting continuing studies to keep these residues within safe limits - by washing if necessary. It is not likely that any extensive use of chemicals other than certain antibiotics for direct preservative effect on food will be tolerated. Certain approved food colors, stabilizers, and so-called condimental additives are used regularly. Necessary studies for control are made by regulatory agencies and there are no current indications that additional special studies are urgently needed.

Food and Diseases

Like common colds, cases of food poisoning are always with us. One of the basic research needs is identification of the toxin of staphylococcal food poisoning and the development of a simple test for detecting its presence in food. Even though very good information is available concerning food-poisoning generally, and reports of outbreaks in the United States and elsewhere are numerous, it is not a killer and we do not have public interest at fever pitch as is the case with more spectacular maladies. Nevertheless food poisoning can be very debilitating and wasteful of manpower in times of emergency. Further study is desirable.

Finally, there is a need for basic study of the possible role of foods in spreading virus diseases. Animal foods contain tissues, perhaps some that will support the growth of viruses. More exact knowledge as to the extent to which viruses may grow and as to how effectively they may be destroyed by the customary means of processing such foods is essential knowledge to those who would control man's environment.

In conclusion we would like to stress the need for a long and broad look ahead before attempting to select categories for research intended to improve man's environment. It is also important to correlate such work with research efforts in other fields, particularly the social sciences, as otherwise we may ultimately wind up with the perfect environment but, just possibly, too many people to share it peacefully.

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PAPER ON OCCUPATIONAL HEALTH PROBLEMS

RESEARCH PROBLEMS IN OCCUPATIONAL HEALTH

by

James H. Sterner

The scope and treatment of this area of our discussion would be much easier if we could confine the concept of "occupational health" to that of a few decades past. The change in focus from "industrial" to "occupational" has widened significantly the field of interest. In addition, the increasing recognition that man-at-work is the resultant of forces and influences from the total environment could, with some validity, extend our reference to engulf a major portion of private, community and public health. It is the importance, number, and urgency of problems more directly related to the generally accepted areas of "occupational health" that will define the limits of our discussion, in keeping with the counsel of the conference planners that our attack be balanced rather than selective and opportunistic. Inevitably, as we develop certain aspects, we shall have to firmly restrain centrifugal impulses, to accomplish even a part of our core objectives.

In our attempt to enumerate some of the more important problems resulting from man's projection into the occupational environment, we shall arbitrarily discriminate three main categories of interaction:

I Man and Hazardous Chemical and Physical Agents
II Man and Machine
III Man and Men

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These categories are not mutually exclusive in their occupational relationships, and the interfusion with elements of the non-occupational environment will be frequent and indistinguishable.

We will pose certain questions which need answers; the emphasis will be on those which are immediate and pragmatic, and without any attempt to establish a priority of importance. The solutions to many of the problems will involve intricate inter-relationships, with important contributions to be developed from other than direct occupational health sources, and the values obtained in this field will find applicability to many other areas. The items cited will be only a small part of the total needs in this field, and with our present limited knowledge and the rapid and expanding involvements of occupation and environment, we can expect many additional questions will arise from each solution to our original queries.

I. Man and Hazardous Chemical and Physical Agents

The problems resulting from the introduction of hazardous chemical and physical agents into the occupational environment make an appropriate beginning for our discussion. Their consideration has a traditional sanction, and the volume and interest of the effort which has been expended, and presently is being devoted, to their control attests the magnitude and importance of the problem.

For a few substances (the American Conference of Governmental Industrial Hygienists list less than 300 threshold limit values) criteria have been established for the purpose of defining a reasonably safe and healthful working environment. The value and limitations of these criteria have been the subject of many excellent and discerning discussions. Few experienced and critical industrial hygienists have illusions that the laboratory experiments and clinical studies from which the more highly accepted limits have derived their validity, apply with equal reliability to exposures actually extending over the full working lifetime.

Question: How reliable are our criteria (such as threshold limits) in terms of remote and more difficultly identified effects - shortening of life span, cancer, interference with work effectiveness? What is the significance of these parameters of exposure to the individual, to industry, and to society?

The problem is not simply that of improving the acuity and accuracy of our methods for detecting injury, or more properly, for determining the absence of harmful effect. Admittedly improvements of this sort are badly needed - and an urgent area for research - but even if we were able to define accurately, in the case of a particular chemical, a slight degree of injury in the complex of other factors influencing remote changes in health or longevity, we would still be faced with the problem of weighing the significance of this finding in relation to the benefits to the individual from his employment, to the costs which industry must meet in applying further control measures, and to the value of the product to our society.

We would be much more complacent with respect to the reliability of our criteria for chemical exposures if the developments in the area of radiation effects were not so constantly and emphatically before us. Even though we recognize the probably broader implications of the radiation problem, the acceptance in establishing threshold limits of such remote measures of injury as shortening of life span and detrimental effects on future generations must cause us concern in contrast with the paucity of such information for many common and ubiquitous industrial chemicals.

If we attempt to extrapolate the effort in terms of personnel, time, and dollars expended to achieve our present knowledge of radiation injury, to the solution of our problems with common chemicals in industry and commerce, it becomes strikingly clear that more effective and more economic technics must be developed.

Question: Can we develop methods for evaluating occupational hazards - particularly remote effects such as shortening of life span, cancer, genetic damage - which will be reliable, practical, and economically reasonable?

With the synthesis of hundreds of new chemical components a year, with the acceleration of the transition from laboratory curiosity to industrial application, the need for more rapid and reliable methods for determining tentative threshold limit values is acute.

Question: How great is the need for more economic and yet more meaningful technics for evaluating the hazard of new chemicals? Who should do it? Who is competent? How do we make the results of such research available to all?

Accidental overexposures occur in spite of our best safety efforts, and with them the need for effective methods of treatment.

Question: How much effort is justified in the development of specific therapy for occupational intoxications? Who is responsible for such research - and how do we stimulate and coordinate it?

The reasonably good safety and health record thus far has been achieved by inserting as large a factor of safety as possible in the threshold limit. Where the engineering or operational control needed to meet this limit has been easily achieved, an excessive safety factor is justified. Where it has been accomplished only with technological difficulty and considerable installation and operating cost, any excess effort must be regarded as wasteful. The decision is not simply one of injury versus dollars, but involves cost of product, standard of living, and ultimately productive effectiveness of the community.

There are many additional problems in this area, which require urgent attention. Little is known concerning the effect from two or more toxic agents in a simultaneous or sequential exposure - a problem in community air pollution as well as in occupational health. What are the relationships, if any, of liminal or subliminal concentrations to the aggravation of disease common to the general population, or to work effectiveness?

The extent of carcinogenic effects from occupational exposures, to chemical as well as physical agents, has had only token study. Reliable experimental laboratory methods must be developed, and new and more discriminating epidemiologic technics applied. The very nature of the problem requires large population studies, frequently involving many occupational groups widely scattered throughout the country.

Question: How do we organize research when the investigation involves a whole industry or segments of industry widely scattered through many communities and states? Who accepts the responsibility for the initiation, coordination and costs?

II. Man and Machine

The problems raised by the interaction of man and machine are no less involved than those described above. The area of direct traumatic injury has become the interest and concern of the safety engineer. Considerable progress has been made with such problems as the guarding of dangerous equipment, the motivating of people to safe practices, and the recognition and acceptance of the importance of accidents in terms of suffering and economic loss. We have much to learn and understand of the basic causes of accidents, particularly in terms of human conduct, before we can achieve the goal of an irreducible minimum.

Question: What kind of research, what new approaches to the problems of causation and of prevention of accidents is likely to give us the greatest yield?

An area in which interest - and concern - is really just developing is the relation of the increasingly automatic machine and the people who operate it. The problems generated involve elements such as fatigue - physical and mental, job motivation, and job satisfaction.

Question: How can we measure effectively, in terms of physical and emotional response as well as work efficiency, the healthful limits of man-machine interaction?

A related subject, with a direct bearing on productivity, is the design of equipment with greater consideration for the abilities and capacity of the operator. A great deal of valuable research on this problem has been done, but better means must be developed to bring this to the attention of and utilization by the design engineer and production supervisor.

III. Man and Men

The relationship between man in his occupation, and his supervisor, his co-workers, his subordinates, his customers, his suppliers of goods and services, is at once the most interesting and the most complex of the environmental contacts. The increasing frequency with which we meet such terms as "human relations", "supervisory training", and "industrial psychiatry" is ample evidence of the awakening recognition that problems involving the inter-relations of people in the occupational milieu are important and need solution. The limitation of time, and the serious doubt that this subject was intended for presentation in this conference will permit only this brief identification of the problem.

Conclusion

These references to research needs in occupational health have been made in general terms and, even thus, included only a portion of the total problems immediately confronting us. Such vital elements as the securing of adequate personnel and facilities connotes the development of training programs, of motivation and education needed to provide the necessary support, of stimulation of a sense of responsibility by industry and commerce, by the community, and by government to see that the job is done.

There is promise, from just such efforts as this conference, that we may progress from a selective and opportunistic attack to one of balance, coordination and broad perspective.

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REPORTS ON GROUP DISCUSSIONS

INTRODUCTORY STATEMENT

by

Henry F. Vaughan

The papers presented by our principal speakers give the impression that there is much agreement concerning our present problems. The following reports will reveal whether this agreement spread down to the discussion groups. Remember that this Conference is directed toward a new vista or new look at old problems of environmental health. While some of the old problems are with us always, and we must keep constantly aware of their implications, there must be new approaches to problems which relate to man and his environment.

Within my brief span of life I have witnessed a terrific commotion about problems of bacteriology, and now find these have been surmounted by other problems which man has chosen to inflict upon his own environment. Let us be forward looking and progressive, and not fearful about conclusions. Let us not tolerate the statements of some that the principles of sanitation are so well known that there is nothing left in this field except to apply these basic principles. We have new problems and new approaches which will be considered today through committee deliberations. While there may not be total agreement, there should come out of the reports of group discussions a platform as to principles and guidelines.

I would hope that we will pay little heed as to *who* is going to do *what* about these problems. I am not as concerned about who does what, as I am about *what we*, collectively, should be doing.

In the health field we have four distinct avenues to which we look: (1) health agencies at the various levels of government; (2) voluntary agencies, some of which are supported by generous donations, and foundations, which are certainly voluntary agencies; (3) other official agencies such as water departments, conservation, engineering and building departments; (4) private enterprise and industry, which must participate because many of these problems are being brought upon us by industry and the only way to solve them is by joint action with industry. The principal and main interest of our Conference is to recommend, carry forward, and support research programs in the interest of the public.

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GROUP DISCUSSION OF RESEARCH NEEDS IN WATER SUPPLY AND WATER POLLUTION CONTROL

Reported By
Gerard A. Rohlich

Summary and Recommendations

We must think in terms of the broadest possible uses of our water resources. Consideration of our changing environment has been forced upon us by our "exploding" population, which has resulted in competition for water for agriculture, for industry, for recreation, and for domestic supply.

Inasmuch as lists of specific research projects have been proposed and are available, our group holds the opinion that the enumeration of additional research projects does not best represent the consensus of thinking by the Conference "Man Vs. Environment." We prefer to recommend the broad areas of research that require attention in the immediate future. These are:

1. Research on water resources management. (Broad consideration should be given to the interrelationships of water uses and water pollution. There should be coordination between the interests of different agencies concerned with water usage, and the impact of one upon the other).

2. Research on the reclamation and utilization of waste waters.

3. Research on the review and refinement of water quality criteria.

4. Research on the ecology of receiving waters. (This research should apply not only to fresh waters but to estuary and receiving waters).

5. Research on the effect of new organic chemicals on receiving waters. (Especially needed are studies of insecticides and weedicides, including analytical methods).

6. Research on the radiological contamination of water supplies.

Historical Guidelines

It was noted that research has already been done if we can point out specific research problems. New developments in science bring about new research needs, and biogenetics are directly related to water supply and water pollution control problems. Research needs are difficult to anticipate, however, and we must remain constantly alert to human ecology in its broadest sense: We have new influences of chemistry on our environment and we have an expanding population, both of which bring competition for water supply and waste disposal.

Lists of Research Projects

The discussion group evaluated the advantages and disadvantages of preparing and publishing detailed lists of specific research projects considered to be in need of study. As several such lists of water supply and water pollution control research projects already are available, it was the consensus of opinion that this group should not prepare a list. It also appeared to be the general opinion that a list presented by the discussion group would carry the implication of approval by the Sanitary Engineering and Occupational Health Study Section for the research projects specified.

Public Health - Related Research

The question was raised as to the requirement that research grant supporg be related to public health problems. It was explained that this is not a restriction: (l) research grant funds are available from both health-related and pollution-related appropriations; and (2) the distinction is more imaginary than real, since it is difficult to find a research problem in water pollution control that is not related to health.

Financial Resources

Reference was made to the level of research support by the Public Health Service. Research grants in the field of water supply and water pollution control total $800,000 in Fiscal Year 1958. There is a backlog of approved, but not supported, research grants amounting to $300,000; and this amount will be further increased before the end of the year. The question was raised as to the need for a higher level of research support: in view of the apparent health of our urban population, is this need real? It was pointed out that, in general, we have no valid means to define the effect of water pollution and of trace substances on human health ("apparent" health is no argument that problems do not exist). The contamination of water supplies by organic chemical compounds may occur from insecticides or from industrial wastes; new problems are created in either instance, and only new research information can provide answers to solve these problems. We need new chemical methods to detect and measure contaminants; we need to study their reactions and degradation products; and we need to learn the physiological and psychological effects of new substances on man.

Availability of Personnel

The group considered whether, if additional support were available, there would be adequate personnel to conduct an expanded research program in water supply and water pollution control. It was concluded that funds, rather than people, were the limiting factor. The reason is that research grant applications would not be made or approved if personnel to staff the projects were not available: there is presently a backlog of approved research projects which could be activated if support is provided. It was suggested that consideration be given (1) to developing means to attract research personnel from related disciplines to the study of sanitary engineering problems, and (2) to developing public and professional awareness of the implications of research contributions to water supply and water pollution control.

Priority of Approved Projects

The question was raised as to the choice of "supported" or "approved" but not supported" projects. It was explained that the Study Section and Council establishes a priority rating for each approved research grant application. The approved applications are then supported, to the extent of funds available, in order of the priority assigned. This procedure favors no particular area of research, but supports what appears to be the most meritorious research.

Questions of Need Vs. Support

The support available for our present research needs is evidently inadequate. Our list of research grant applications which are approved but which cannot be supported is evidence of this. This backlog of research may be clear evidence of need, but the question was raised: "Is it the Public Health Service, or is it Congress, that must be convinced of the need in this area?" Apparently the Public Health Service should be advised by competent groups, such as this, that additional research effort should be devoted to specific problems; for example, the newer types of chemical contaminants. When sufficient concern is expressed, action can be taken to give special attention and emphasis to these problems.

Broad Areas of Research Emphasized

The group devoted major consideration to discussion of broad areas of water usage and water pollution; it considered that complete integration and coordination of these is needed. Leadership should be provided by sanitary engineers in the entire area of environmental control. Research on the radiological contamination of water should be more actively considered by the Public Health Service. The problems of water pollution by organic chemicals, including insecticides and weedicides, are especially in need of study. Water quality criteria should be reviewed and refined, as an important guide for regulatory agencies. Quantity considerations must be involved in water resource management, and economic considerations should be evaluated.

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DISCUSSION OF REPORTS ON RESEARCH NEEDS

WATER SUPPLY AND WATER POLLUTION CONTROL

Jack E. McKee:

It should be noted that the discussion group preferred to emphasize important areas of research needs in the field of water supply and water pollution control. This group considered the desirability of preparing a list of specific research projects, but decided that the publication of such a list would imply that research grant applications based on such projects should be approved by the Study Section. It is clear that only the broad fields of research needs should be delineated.

Karl Z. Morgan:

It might be of interest to report that Health Physics Division, Oak Ridge National Laboratory, is now developing values for the permissible concentration of radioactive nuclides in air, water, and food. These data have been completed and represent six years of effort; we hope to submit the manuscript to the publisher late in 1958. This is a revised list for occupational exposure. Handbook 52 has values for 74 isotopes, and the new one has values for 240. In the last handbook we combined efforts of both national and international committees. We now plan to get out a single publication on internal dose. It seemed absurd to get out two separate ones. We will strive to have a single publication.

When one gets ready to apply maximum permissible exposure values to the population at large he runs into certain difficulties. We are recommending that these occupational values be reduced by factors of 10 for the general population living in the neighborhood of the occupational exposure area. The problem becomes more difficult when we begin to think of applications of these values for the population at large. All of you are familiar with the recommendations of United Nations Radiation Committee, NRC Committee, and other groups working in this field. All of them have recommended that the exposure to the population at large be of the order of the natural background radiation.

Gordon M. Fair:

I have the feeling that perhaps our major problem is one of personnel. I don't think that the provision of more funds can be justified until we are able to build up personnel capable of doing fundamental research. We have failed to attract into our field enough qualified chemists, biologists, and physicists to do fundamental research. The engineer who provides the stimulus for the development of research is often not the person to carry on the proposed research project. His own sphere of activity is associated with his competence in mathematics, hydraulics, and hydrology. For chemistry, biology, and physics, he must lean heavily upon the pure scientist. This lack of suitable scientific personnel is one of the critical phases through which we are passing at the present time.

Gerard A. Rohlich:

Professor Fair has reemphasized this important point. How can we go about attracting basic scientists into our area? The team effort at the Sanitary Engineering Center is an excellent example of this. It is difficult to get chemists and biophysicists to devote themselves to this particular area and I don't quite know how we are going to go about this.

Erman A. Pearson:

I would like to make one point relative to Professor Fair's remarks limiting the engineer's area of activity to mathematical problems. I think that in the field of water supply and water pollution control, for example, a good portion of the applied "research" will be done by engineer-scientists as well as by chemists, biologists, and other basic scientists. Also, I inferred from Professor Fair's remarks that he overlooked or excluded chemical engineers working in these fields. Certainly in these fields there are an increasing number of chemical engineers and these individuals should not be limited to mathematical problem areas. Moreover, chemical engineers are particularly well qualified and suited for work in applied physical chemistry research.

Regarding the shortage of personnel, I still think one of the basic problems is related to dollars. If reasonable salaries could be paid to support young engineers during graduate study and research, we could attract and develop more scientifically oriented engineers capable of advancing the level of the profession in the many complex subject areas discussed here today. I do not mean to imply that it is necessary to compete on the open market with industry for B. S. trained engineers; however, we must attract a higher percentage of our competent B. S. level engineers to graduate study and research.

Richard D. Hoak:

At Mellon Institute, my fellowship is encouraging young men to enter this field. We have employed three high school boys who have had an interest in chemistry. We have the happy arrangement at Mellon Institute of permitting junior personnel to work in the University of Pittsburgh on the basis of 6 semester hours, tuition-free. This arrangement is good. One boy has considerable aptitude for the kind of thing we are interested in, and I have every expectation that he will develop into a useful research worker in this field. There have been several instances in which this sort of thing has been done with a great deal of satisfaction.

It seems to me that the university faculties must address themselves to the question of showing their students the intellectual satisfaction that there is in carrying out research in this field. Many fields of research have been glamorized much more than this one. This is an enormously interesting field despite the fact that sometimes financial rewards are not what they should be. Money isn't everything, and somehow I feel that the university faculties might perhaps do a somewhat better job of inspiring their students to become professional research workers in pollution control. We know from the newspapers that cancer, polio, heart diseases and similar disabling illnesses have perhaps captured the public imagination to the extent that our particular field suffers by comparison, in that the necessity for carrying on basic studies that are so important to a better understanding of the kind of problems we are seeking to solve has suffered materially.

Henry C. Marks:

I would like to give emphasis to the other side of Pearson's question. There is the problem of the type of scientist who should perform this research and also the question of motivation, particularly with regard to money versus other incentives. It is true that you need a certain amount of engineering science in this field but I suspect that the predominance of engineering science might have given rise to the remark that all the principles of sanitation have been worked out. I believe that what has happened in this field is like others: engineering science has caught up and outstripped fundamental science, and further advances in environmental health will depend on advances in the fundamental sciences.

Another point is the question of motivation. How do you get the fundamental scientist into this field? A certain amount of money is necessary, but you can't compete simply on the basis of money. Every scientific field can offer money. Almost any scientific field can offer the incentive of work for the public good. I don't believe that either of these is the primary motivation for scientific work. I believe the thing that primarily motivates a scientist and makes him want to do work in a certain field is intellectual accomplishment - intellectual level.

One of the difficulties we have had in getting people into this field is that we have failed to identify problems that really do require a degree of intellectual attainment and intellectual ability worthy of most scientists. I must confess I feel uneasy about saying this because I hate to pose problems without answers. I don't have an answer. I feel that it is necessary to outline and spell out the intellectual requirements and the intellectual interest that can be found in the fundamental problems in this field.

Harold B. Gotaas:

I would like to comment further along the line of Dr. Pearson's remarks. I think that Dr. Fair's remarks deal with the past and not the future. The engineering profession is moving more and more toward the science aspects. The January report of the National Science Foundation shows that about 25 percent of the engineering profession is engaged in research and development, which, according to the survey, constitutes 139,000 engineers; 40 percent of the physical scientists are engaged in research and development, which is approximately 60,000 individuals. One shortcoming, particularly in sanitary engineering, is that in the past we have not emphasized the research and science aspects and we can't depend on the scientists to do this for us. We have to educate the engineer to be more interested in research.

Another limitation in sanitary engineering has been our emphasis on public health administration. Over the years public health schools have not been very research minded, but have dealt more with an administrative type of education. We in sanitary engineering have been more associated with the administration, rather than with investigation of what really are the problems - so that we can administer them better. To me the answer is gradually being accomplished, but not rapidly enough. I agree with Dr. Fair that the engineering profession has not been sufficiently progressive in science and research. We should get busy and get a more scientific and investigative approach in our research programs. Engineering today however, is developing more people with an interest in research.

Thomas R. Camp:

I have heard no denial of Prof. Fair's statement that we are lacking in competent research personnel. I have had the feeling for many years that we can lay this difficulty at the door of undergraduate training in civil engineering. As you know, the sanitary engineer evolved as a branch of civil engineering. Nevertheless, the field of sanitary engineering has since become even broader than most civil engineers will admit. The Civil Engineering Department in the universities have over the years had little or no interest in sanitary engineering and sanitary engineering professors have had to go their own way to get something done. The result is that there has been much too little undergraduate education in chemistry, biology, etc.

In 1952 a report by the Grinter Committee of the ASEE recommended in general the abolition of options in undergraduate engineering curricula in an endeavor to train all engineers with a single undergraduate curriculum, which would include all of the basic sciences and engineering sciences required for any type of engineer. Many of us thought that was a big order; I don't think it is a big order for civil engineers. I have thought for many years that undergraduate training in civil engineering should be in that direction, to include all the basic sciences required by all branches of civil engineering, including sanitary engineering. If that is done then all graduates of civil engineering courses would be good material for post graduate work in sanitary engineering because they would have had the basic sciences which would qualify them for first rate research in the sanitary engineering field.

Bernard B. Berger:

I would like to speak on the subject of sanitary engineering and fundamental research. I do not believe that the sanitary engineer in research can, with his training, generally undertake really basic research as this term is defined by fundamental scientists. In my opinion, the most effective contribution that the sanitary engineer in research may make is to bridge the gap between the applied scientists, including sanitary engineers, and the fundamental scientists. I should like to describe three recent experiences at the Sanitary Engineering Center that suggest why sanitary engineers must lean on others trained in the fundamental sciences rather than accomplish difficult jobs by themselves:

(a) Our staff in bio-chemistry has recently obtained rather interesting results in an attempt to apply serological techniques, e.g., antigen-antibody response reactions, as sensitive procedures for the identification of specific chemical substances present in trace concentrations. Here, we sanitary engineers must borrow heavily from the medical scientists rather than attempt to undertake fundamental research of our own. The sanitary engineer is not equipped to undertake fundamental research of his own. Instead, he must depend on individuals with considerable training in the bio-chemical sciences for fundamental advances in this interesting technique.

(b) Another recent situation involves the observation by a member of our staff, a microbiologist, that viruses suspended in water are removed by floc particles themselves in colloidal phase, at a rate that appears to vary inversely with floc particle size. Here, we have a suggestion of the worthwhileness of fundamental studies of adsorption phenomena and of the potential contribution that the colloidal physicists may make to our understanding and use of improved coagulant procedures.

(c) Just a few weeks ago, an interesting incident occurred involving the souring of activated sludge in our experimental units. We had to depend on our mycologist to elucidate the reason for the sludge deterioration. He found it was due to a fungus that was predatory on rotifers which are very important in the ecology of a healthy activated sludge.

These incidents point up the need for sanitary engineers in research to depend on fundamental scientists and the need to build communication bridges with such workers, many of whom may never have heard of sanitary engineering or its problems. Incidentally, our experience has shown that scientists in basic research often find sanitary engineering problems attractive and satisfying research opportunities.

Thomas R. Camp:

I think I stirred up a hornet's nest. I was answered by Berger. I would like to reassure Berger that I am not at cross purposes with him. He intimated that I was in favor of sanitary engineers handling all of the research. We must of course call in the other disciplines. My point was this - as far as the water and waste disposal field is concerned most of the young men who come into it are civil engineering graduates and that is apt to remain the case in the future. They are the men, if they turn into sanitary engineers, who are responsible generally for administration of research. That being the case, they will do a better job and they will align themselves with trainees in the other disciplines more properly if they have had a broader basic science training in undergraduate civil engineering.

Emil M. Mrak:

Food technology is an applied field of research. We have experienced the same type of problem in our field at the University of California. We concluded that we should have in our department more people with the Ph.D. degree in a basic science than in food technology as such. The person employed, however, must (a) have or be willing to develop an interest in food technology, and (b) design a research program with a food technology point of view. A 3 to 1 ratio of fundamental scientists to food technologists appears to me as ideal. We were anxious to develop teaching and research in the areas of fats and oils, flavor chemistry, proteins, etc., and have employed scientists trained in these areas. One man cannot be made into everything. We gave up on that idea some time ago. We have found that good, fundamental scientists not only attract graduate students, but attract good ones.

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GROUP DISCUSSION OF RESEARCH NEEDS IN AIR POLLUTION

Reported By
V. G. MacKenzie

The principal topics discussed by the Air Pollution Panel Group can be grouped as follows:

1. Specific research needs.

2. The balance of desirable research effort as between biological (principally health effects), physical science, and engineering studies, or the relative priority which should be given to each of these.

There was full acceptance of the necessity of recognizing the limitations of the atmosphere as a natural resource in diluting and dispersing pollutants which will certainly be reached increasingly in many urban areas unless appropriate preventive action is taken. There was agreement also that air pollution research should include consideration of aero-allergens, whether of natural or man-made origin.

With respect specific research needs in the field of air pollution, the Panel endorsed a composite listing made up of the following:

1. The specific suggestions included in the papers presented yesterday by Dr. McCabe and Dr. Chambers.

2. A list of categories of research on the effects of air pollutants on human health as presented by Dr. Fisher of the Public Health Service.

3. The listing of needed physical science and engineering research developed at the Research Planning Seminar held at the Sanitary Engineering Center in February 1958.

Since the second and third items have not been presented to this group heretofore, a brief outline of them may be in order.

The Fisher listing of needed research on the health effects of air pollutants includes the following five categories:

1. Research on long term effects and exposures - embracing both experimental and community studies.

2. Research on toxicological and physiological effects of pollutants, both acute and chronic.

3. Evaluations of respiratory disease, in general and in particular, in relation to air pollution exposures.

4. Evaluation of the effects of exposure to total composite community air pollution (including the effects from sub-total composite pollution such as from auto exhausts).

5. Development of improved techniques for community assessment of health effects through epidemiological studies.

It was agreed that any positive findings in community epidemiological studies would require in follow-up more precise focusing of attention on specific pollutants for pin-pointing of cause and effect relationships.

At the Research Planning Seminar at the SEC in February of this year, six committees developed relatively detailed categories of air pollution research needs. The respective committees concerned themselves with: aerosols, chemistry, meteorology, instrumentation, agricultural effects, and engineering. The Committees made no effort to establish priorities.

I. The Committee on Aerosols. It recommended two general categories of research:

(a) Those areas directed at understanding the system to be controlled. This category included:

1. Study of the formation, growth and fate of aerosols. (Evidence indicates relationships between formati process of

certain types of particulates and irritative and other nuisance properties in polluted atmospheres.)

2. Reactions between particles and gaseous pollutants. (Much remains to be elucidated as to the dynamic equilibria in systems as affected by physical and chemical parameters.)

3. Characterization of aerosol particles with respect to composition, energy state, and other parameters.

4. Sensitization of reactions at the interface between particle and gas.

5. Relation of particles and their processes of formation and growth to biological irritation, plant damage, and other effects of pollution.

(b) Research needs for immediate application in control:

1. Collection and collation of data as to size, physical and chemical properties of particles from various pollution sources.

2. Collection of data to establish patterns of variation in distribution of aerosols in relation to various sources.

3. Development of specific measurement and analytical techniques and instrumentation.

4. Correlation of visibility with atmospheric aerosol content.

5. Source control of aerosols.

II. The Chemical Committee. This committee's considerations were essentially limited to problems of sampling and analysis:

(a) On sampling, the principal emphasis was on gaseous contaminants, with recommendations for further study of methods using absorption by scrubbers, etc., adsorption, and freeze-out.

(b) On analytical procedures, it suggested further study and development of a wide variety of procedures was recommended - gas and liquid chromatography, infra-red and mass spectrometry, polarography, microwave spectrometry, bioassay procedures, and others.

III. The Meteorology Committee. It considered one problem of prime importance - the quantitative specification of atmospheric dispersal capacity. Three categories of needed research were listed:

1. Meteorological aspects of specific community studies (dilution, zoning, sampling, locations, etc.)

2. Meteorological research directly appliable to community air pollution. Principal recommendation in this area was for a comprehensive study of the intermediate and large scale processes (0 to 50 miles) involved in the 3-dimensional transport and dispersal of contaminants.

3. Basic research on such subjects as atmospheric turbulence, microclimatology, and meteorological measurements to extend the scientific basis for more immediately practical studies. The Committee devoted attention also to specific needs for instrumentation for various purposes, the use of tracer materials, use of models, and other accessory research needs.

IV. The Instrumentation Committee. Its recommendations can be summarized very briefly: Instruments are most needed for:

1. Gas phase pollutants - at sources in the free atmosphere, and in the laboratory.

2. Aerosols - again at sources in the free atmosphere, and in the laboratory.

3. Visibility in the atmosphere.

V. The Agriculture Committee. Its basic recommendation was for expansion (or initiation) of fundamental research on the effects of practically encountered concentrations of various pollutants and of mixtures on plants and animals.

VI. The Engineering Committee. This committee made a plea for more support of basic research, voicing dissatisfaction with progress and pointing out that current air pollution research expenditures amount to about 0.1% of the estimated economic burden of air pollution to the nation.

It recommended first consideration for control by process design or modification. In other instances it recommended acceleration of research for control procedures on a variety of pollutional discharges--from pyrometallurgical processes, internal combustion engines, steam generating facilities, incinerators, etc.

Largely for evaluation purposes, it recommended emphasis on several other categories of research, such as - collection and collation of data on the quantities and characteristics of atmospheric pollutants; the deposition and retention of pollutants on surfaces; the development of improved control evaluation techniques, involving reliable solid and liquid test aerosols, and improved subjective measurements for such parameters as eye irritation and odors.

In the discussion by the Panel on the relative emphasis to be given to health effects, physical science, and engineering studies respectively, no decision was reached as to relative priority between these categories. One participant received support in the viewpoint that research on health effects should have top priority, at least in work supported by PHS funds. However, the consensus appeared to be that research is needed in all categories and that available resources should be channeled to specific projects on the basis of urgency of need and expected productivity, without being bound by rigid priorities by category.

No specific "resolutions" or "recommendations" were adopted by the Panel other than those which are implicit in the suggestions for needed research, including the support required to carry it on.

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DISCUSSION OF REPORTS ON RESEARCH NEEDS

AIR POLLUTION

Leslie A. Chambers:

There is one area in which the recommendations formulated by the various committees was deficient. The members of the committees assembled to consider the chemical problems of air pollution decided early in their deliberations that the makeup of the committee was such as to make it inadvisable for them to consider problems involving reactions occurring in the atmosphere. The majority of committee members were analysts. They took the position that recommendations on atmospheric chemical reactions would have to be deferred until next year, or until a more adequate representation could be made.

This situation illustrates some of the implications of comments by Professor Fair. We had a situation in which trained chemists were applying themselves to research in the air pollution field, but they concluded that their specific disciplinary interests were not adequate to cope with the challenging and difficult problems which lie in the field of chemical kinetics. The chemistry of air pollution has proceeded in the past seven years at such a pace that it is impossible for those of us who are charged with staffing laboratories to consider categories of professional interest. We have to consider the requirements of the particular problem and, no matter what a man calls himself, if he has appropriate qualifications we hire him. The breakthrough has come from photochemists, biochemists and other variety of persons. In no case are they concerned with particular professional connections.

Vernon G. MacKenzie:

This omission was recognized in the report.

James H. Sterner:

This discussion emphasizes the need for a synthesis of the cumulative effects from all of our respective environmental contributions. Who is to accept the responsibility for adding up and balancing the various elements? How do we develop the "generalist" to deal with the total problem created by all of these special areas?

John J. Phair:

One approach to the problem is to bring into graduate teaching the general concept of epidemiological methods and their applications. We don't know exactly how to involve in our graduate training in occupational health and environmental medicine all of the people and disciplines concerned. In tackling most research problems today there is the necessity of bringing together competent individuals of broad experience and training in many areas. We must learn what can be done to get those people engaged in research and teaching in the fundamental sciences into a working relationship with those in physical and engineering sciences so that they recognize certain areas in which they can be mutually helpful. This must be started cautiously until it is known what can reasonably be done.

My belief is that neither engineers or physicists are sufficiently trained in the basic sciences to go off and study these problems alone. Somehow or other they must get greater depth of training at the same time. I am fearful that the basic scientist, by the very nature of his work, is not going to venture into these fields of needed activity until and unless we can bring him into the field by showing him that these are problems in which he can help.

Many of these problems in the field of applied science are as interesting and valuable as most of the ivory-tower projects that the basic scientist customarily chooses. I don't think the needed challenge is having more money but of being of some service to humanity. This is the thing that catches the interest of the medical scientist. No problem is too great or too small if it ministers to the health and welfare of human beings. We should use this opening to bring into this field those individuals whose talents are most needed.

John Wister Meigs:

I would like to speak on this subject from the point of view of occupational medicine. Over the past few years it has become clear that scientists working in a variety of fields are meeting the same basic problems; problems of biology, chemical enzymes, protein chemistry, etc. I would like to make a plea for an arrangement in which many are concerned - a plea for closer integration of teaching in schools of public health and schools of medicine. We have an opportunity in schools where there is a public health program to indoctrinate the undergraduate medical student with better understanding of the influence of environment on health. Most physicians today are not well prepared in that. Many are hardly prepared at all.

There has been a tendency in the past couple of years to separate even further the training of people in public health from the training of people in medicine. This I believe is a step in the wrong direction. I believe that if we are going to be jointly concerned with effects of environment on man we should try every step possible to bring together professionals in areas where they are jointly concerned. I am not suggesting that we teach details of engineering or chemistry to physicians, or details of medicine to engineers or chemists, but I am suggesting that unless we bring them together more in their training process they will continue as at present to operate as if those in the other fields do not exist. These individuals may face a problem 25 years later and find out that there is a whole body of information of which they are ignorant.

Vernon G. MacKenzie:

This interdisciplinary mixing should take place not only in the schools but operational environment as well. In the air pollution program we have been impressed with the need for interdisciplinary cooperation. To promote the necessary cooperation between these disciplinary groups we have to mix them some way. This is hard to do and there is an inherent resistance to it. It has been attempted in part by the Public Health Service in some meetings and in part by some other organizations with mixed success. It is not all straight forward and easy to do.

Jack C. Carmichael:

Within this field of occupational health and public health we have need for each of the professional disciplines. We in the Air Force recognize the need for each one. We strive for and emphasize a team approach. No individual, regardless of whether he is a doctor, an engineer, or a chemist, has knowledge to solve all problems. This is where I want to take exception to some of the recent philosophy. We should retain our individual professional categories. We should work together as a team on the job. Our observation in the Air Force is that we need a cross section of engineers. We use civil, mechanical, electrical, chemical, and sanitary engineers in our program.

I am appalled at the lack of information that a great majority of young engineers have about our program, about the field of sanitary engineering, and also about the field of industrial hygiene. We have great need of indoctrinating undergraduates in how important, fascinating, and interesting this field of sanitary and industrial hygiene engineering can be. We have found our greatest success when we work young engineers hard at a professional level and treat them as professional people. I feel we must keep both individual professional identity, and weld the individuals together as a team.

Arthur C. Stern:

We, too, have had the problem of where to obtain people to do research in air pollution. We have decided that the conventional trained sanitary engineer is not the man to do it. His whole basis for training has not fitted him for air pollution research. We have had to adopt the approach of bringing people in because of their specific chemical or physical specialty. Even beyond the specialties mentioned - chemistry, biology, etc. - our research is pulling us into areas where we can't employ trained people, i.e., in electronics, missiles, etc. In these fields we have to get consultants by contract from places where these types of specialties exist.

William L. Faith:

I think there was no intention of playing down the need for work on the chemistry of polluted atmospheres. We have only scratched the surface in this field. About 80 percent of the work being sponsored by the Air Pollution Foundation is on the chemistry of a specific atmosphere - irradiated auto exhaust. No work is being done on the chemistry of the dark reaction. One other item: Mr. Stern made a plea for the establishment of outdoor maximum allowable concentration of materials. This would be a most difficult matter, but there is a need for an understanding of what are maximum allowable concentrations of various gases in the atmosphere.

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GROUP DISCUSSION OF RESEARCH NEEDS IN FOOD TECHNOLOGY

Reported By
David B. Hand

Summary of Principal Topics Discussed

1. Food is a major component of man's environment. The determination of the total amount of contamination from the environment is heavily dependent on the amount supplied by foods. Foods exert a primary effect on the physiological well-being of man. In addition, foods support the survival as well as the growth of micro-organisms and foods are potential carriers of chemical and biological contaminants from soil, water, and air.

Food environment is both microbiological and chemical. With respect to the microbiological aspect, it is significant to note that food poisoning has not declined in step with the drop in water and milk-borne diseases. With respect to the chemical aspect of the food environment it must be admitted that food is a milieu whose composition is largely unknown.

2. Man's food environment is undergoing rapid and continuous changes as a result of the following:

a. Shifts in food habits to the expanding use of "convenience" foods.

b. Introduction of new methods of food technology, through all stages of handling from the farm to the dinner table.

c. Intentional and inadvertent addition of additives.

3. It is important to define the role of public health agencies in relation to foods because of the interests of other agencies. The following areas are of primary concern to the public health agencies:

a. Prevention of illness caused by or transmitted by food.

   b. Studies of the influence of food habits and dietary practices on physical and mental fitness.

   c. Appraisal of the public health significance of new developments in the production, handling, processing, storage and distribution of foods.

4. Among the ways in which public health agencies can carry out their functions are the following:

   a. Assume leadership in surveying new products and practices.

   b. Search for improved means of determining the occurrence and significance of food-borne illnesses.

   c. Develop methodology for laboratory and field use.

   d. Develop criteria for food safety.

Examples of Specific Research Needs

1. Study the occurrence and survival of viruses in foods.

2. Study the occurrence and survival of micro-organisms in commercially prepared, ready-to-eat foods.

3. Determine the effects of the use of antibiotics in foods and feeds on the development of resistant strains of micro-organisms, including pathogens.

4. Study the ecology and taxonomy of organisms causing paralytic shellfish poisoning.

5. Evaluate the significance of contamination of foods by radioactive materials.

6. Develop improved toxicological methods for evaluating the chronic effects of food additives.

7. Evaluate the new ultra high-temperature-short-time methods for heat processing.

8. Study the epidemiology of salmonellosis and staphylococcus food poisoning.

9. Determine the dosimetry and post-radiation effects in treatment with ionizing radiation.

10. Study the chemical deterioration of foods, including browning, rancidification, etc.

11. Isolate and identify substances formed in foods as a result of food processing.

12. Investigate pesticides, including systemics, synergistic action, and accumulation in soil.

Recommendation

Since foods constitute a dominant component of man's environment that is continuously undergoing change, and since the changes go into application stages before their effects on public health have been properly appraised, it is recommended that a significantly expanded program of research in food technology be supported and encouraged by public health agencies.

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DISCUSSION OF REPORTS ON RESEARCH NEEDS

FOOD TECHNOLOGY

William J. Darby:

The report of the group discussion summary was excellent. The question of research on food additives among the research areas needs some expansion. A major need is for an exploration at a fairly basic level of new approaches and new methodology for studying additives. We talked about appropriateness of the Public Health Service - of a public agency - supporting research on food additives; here you have a slightly different situation than with air pollution, since food additives are put into foods by individuals who are selling products. Perhaps one should say all research should be done by individuals using it. There are, however, many additives which have been used for generations on which we don't have sufficient knowledge or appraisal. Where is area of responsibility for research on these? Is it not in part, at least, governmental? One can say there is reason for government support of those studies which deal particularly with problems of methodology. Chronic studies on food additives cost thousands of dollars in order to get information on a specific product. We need critical methodology in this area. We need investigations which are aimed directly at developing new approaches, methodology, and exploration of ways of avoiding 2, 3 and 5-year chronic studies. I think this is an important point for us here.

As I sense the discussion in air pollution and other environmental factors, this is not different than the problem which underlies these fields - the basic approach to appraisal of health impairment. The other point I wish to stress is the same plea made earlier by others for training and recognition, and of the need for personnel in this field. One of the greatest problems is finding trained persons who have interest and background, or who have thought about the study of food additives as an area for research.

John D. Faulkner:

I would like to discuss briefly the need for utilizing the team approach in the conduct of our food control programs, including research, as well as the need for broadening the training of sanitary engineers to include some undergraduate work in food technology. Milk and food sanitation are areas of public health work where we would be pretty much at a loss, as the technical skills required are concerned, if we relied entirely on sanitary engineers. In the Public Health Service activities concerning milk, food and shellfish, we have found it necessary to employ a number of professional competencies. The disciplines utilized in our programs include sanitary and mechanical engineers, bacteriologists, dairy technologists, food technologists, veterinarians, and food chemists. To solve some of our problems, we seek outside support from epidemiologists, virologists and other medical skills, and from physicists, radiologists and statisticians. One of the things which has disturbed me is lack of attention by the schools of sanitary engineering and of public health to the public health aspects of the milk we drink and the foods we eat. We need sanitary engineers in the public health profession who have some interest in food technology and a minimal knowledge of the environmental aspects of the subject. Young engineers who have recently come into the Public Health Service have no interest or background in these aspects from their academic training.

Another point I would emphasize is the attitude which leaders of many public health agencies have developed regarding the protection of milk and food as a public health problem. Public health agencies made a tremendous effort years ago on milk and food sanitation because it was proven that milk and food served as vehicles for the transmission of communicable diseases. Large funds were appropriated and crash programs were instituted. Now we have developed a sense of complacency and have allowed these programs to suffer, especially in the research field. Many methods, including analytical ones, long utilized as safeguards, are in danger of becoming obsolete. I would like to illustrate this point. We have accepted pasteurization as the necessary safeguard to protect our market milk supply. New milk processing methods recently have been developed and are used by industry, which raise the temperatures but lower the holding times on which we now rely for proper pasteurization. We have little information on which to accept these new processes except that which has been extrapolated from sketchy studies made 25 years ago. We are moving up into the temperature range of 185-230 degrees Fahrenheit with practically no holding time whatsoever. In fact the time of holding in these new processes is so short that an instrument to control flow time cannot be developed at a practical cost, and thus the time must be controlled through the designing "time of passage" into the equipment. This is but one illustration.

That there are many other problems has been brought out in our Committee's report. We just don't have research support of the kind needed to assure the public that the milk and food they eat is safe. I would like to call to your attention the fact that we are now facing new disease entities that may be transmitted through our foods. In recent years we have had to face the problem of "Q" fever. In addition, there is the problem of virus transmission which most of us feel needs study. The safety or our milk and food is of definite concern to the public, and the needs for research in this area cannot be shrugged off on the basis that the problem is well taken care of.

George F. Garnatz:

I would like to add further emphasis to what Mr. Faulkner said: I think the Public Health Service has done a splendid job in the area of milk technology. I believe that by analogy the things which have been accomplished there in the interest of public health, in services to the states, and in an advisory capacity might be carried into the broad field of food. To further emphasize the desirability for expansion of work by the Public Health Service in the field of food - this material that we ingest three times a day is the recipient of contaminants that are in water, soil, and air and, in fact, constitutes an accumulation of these things. I believe, therefore, that it quite logically falls in the domain of concern to the Public Health Service.

Robert A. Kehoe:

What I have to say relates to toxicology. When we investigate water by itself, air by itself, and food by itself, particularly with reference not to substances that are added to food purposefully, but to advantitious contaminants, we find ourselves in situations in which it is not possible to establish realistic standards for human safety. It is worthwhile to remark that particulate materials that are retained in the lungs, except as they are completely inert, are absorbed in toto, and are distributed throughout the organism. Since many materials are but poorly absorbed from the alimentary tract, what is in the air may be more important than that which is in food. We should cultivate a community of interest and activity in this field, so that the total quantities of potentially toxic substances in food, water, and air may be considered together.

In toxicologic investigations we tend to be too much limited to the laboratory and too much concerned with the study of the laboratory animal and his reaction to a particular situation. Moreover, experiments concerned with the feeding of contaminated diets to animals tie up facilities for long periods of time. This is expensive and time consuming and secures only a piece of the answer. There is another means of approach to toxicologic investigation, with which not many toxicologists at the present time are adequately concerned. Exposure to toxic chemicals often occurs at a relatively high level among people working in industry. In many cases, these represent, in greater or lesser degree, a captive population. They can be studied with a reasonable amount of effectiveness, in that under known environmental conditions, one can observe the response of individuals to higher dosage than those likely to be met with in the general population.

There are many instances in which we can establish the tolerable level of exposure of the industrial population and translate it into terms that relate to the entire population. In short, we can establish tolerable levels for human beings with a greater degree of accuracy and with less expense in the long run than we can for laboratory animals, and with a double-barrel result: protection for the people in industry and a better knowledge of what is required for the protection of the public. I suggest that the industrial population is not sufficiently regarded as a logical experimental site for observations of this type, and I bespeak more attention to occupational hygiene as a source of toxicological information.

David B. Hand:

In regard to suggestion by Dr. Kehoe about emphasis on the use of industrial populations, the study of tolerances to additives applies largely to inadvertent additives. We are doing two-year animal tests to get a line on intentional additives. There are some examples of occupational diseases resulting from work in flavor factories.

Some of the flavors used in food are toxic to workers in plants. Can we draw conclusions with respect to safety for food use, from observations on industrial illnesses?

Darby:

I don't think we should leave impression that we are condemning two-year studies. A fine example is metabolic studies which have completely eliminated necessity for 2-5 year chronic toxicity studies. It is for further exploration of other research approaches that so many of us would like to make a plea.

GROUP DISCUSSION OF RESEARCH NEEDS IN OCCUPATIONAL HEALTH

Reported By
J. Wister Meigs

Discussion by this group related to two general areas of research needs:

1. Methods for appraisal of occupational hazards in the laboratory and in the field.

2. Applications of epidemiologic methods to the total field of occupation in order to learn the impace of occupation on man. Inherent in learning what may be the impact of occupation on man is the need for information about the common chronic diseases.

Principal Topics Discussed

Although methods for studying occupational hazards are being used regularly and many new chemicals are being evaluated for toxicity, the number of new compounds and new combinations of old compounds is almost infinite even over a short space of time. It was suggested that one approach to this might be continuing surveys of what is actually happening in industry, with some quantitative estimate of numbers of situations in which a new compound is used and numbers of workers exposed. Results of these surveys could be used as a basis for priorities in determining what research needs to be performed. Admittedly this does not answer the problem of avoiding introduction of every hazardous new chemical or combination.

The need was stressed for coordination of occupational health research with other research in public health as well as preventive medicine. It was pointed out that many, if not most of the problems mentioned at this conference had come about because of industrial technology. Closer integration of occupational health activities with professional efforts in related fields might permit meeting research needs with conservation of overall effort. Mutual understanding between personnel in different areas of public health is part of the research problem.

Specific areas for study which might contribute to understanding the effect of occupational hazards on man included: Physiological and biochemical studies to provide methods for detecting minimal deviations from normal. These should include the exploration of previously unexplored or only partially explored biological systems. The response of ciliated epithelium to small doses of toxic chemicals is an example.

Results of this kind of study might provide much needed information on what to look for in the environment. If we knew what to look for, we might then set up projects to determine how to detect these environmental factors.

These studies would also include consideration of man's basic physiology in relation to work stresses. One example might be exploration of the effects of physical effort, that is, exercise or lack of exercise on a variety of physiological functions.

In relation to control of occupational hazards, including accidents, studies are needed on man's behavior, to try to learn more about why he does what he does.

Regarding the need for application of epidemiologic methods, there was considerable discussion of the related problems of personnel and facilities. Although these problems also are important in relation to laboratory studies previously summarized, they are particularly acute for epidemiological studies. Complete and accurate records of workers rarely are available. This is not just because of administrative problems in prying records loose from medical departments. The actual records rarely contain the details needed for a particular epidemiological study. One reason is that the doctors and nurses who maintain these health records rarely are trained in epidemiology and are therefore not alert to the possibilities. Expansion of numbers of epidemiologically trained physicians is necessary. It was suggested that occupational health teaching programs should stimulate faculty members in all other special areas of medicine to recognize the opportunities for finding some of the answers to their problems about chronic diseases through cooperation with specialists in occupational health.

Another major need is an increase in the size and scope of the occupational health program of the Public Health Service. It was emphasized that present budgetary restrictions do not permit needed laboratory studies or epidemiologic investigations even on the old, well recognized occupational diseases.

There was general acceptance of the need for careful studies of the development of chronic diseases in employed adults. These epidemiologic studies might provide a baseline for evaluation of the influence of specific occupational hazards. It was recognized that these studies would be basic to all adult health efforts. This again emphasizes the need for the team approach and interchange of information among all professional groups concerned with a particular health problem. For example, in all these epidemiologic studies, sociologic and economic information should be developed and included.

No formal recommendations were adopted but it was the consensus of the group that greater support should be given to the Public Health Service program in occupational health. There should be continuing close coordination of this with the health areas represented at the Robert A. Taft Sanitary Engineering Center.

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DISCUSSION OF REPORTS ON RESEARCH NEEDS

OCCUPATIONAL HEALTH

Theodore F. Hatch:

I have been impressed with the fact that we have been spending more time in discussion of how to get people with proper competence and special skills to work on environmental health problems than with the significance of one area of research as compared to another. It would not be difficult for anyone here to write down a list of items on which research is needed. So, we have turned to the question of how to get research done. We have agreed on the need to bring people into the field from the basic sciences.

In the field of occupational health, I have seen the field develop during the last quarter of a century from the time when it was essentially research--in the field, as well as in the laboratory. As findings of research became available, more and more people became occupied with application of this knowledge to the solution of occupational health problems. There has been great dependence on the use of principles and techniques which came out of this early research. Today we have engineers whose primary interest is directed toward details of the environment. Chemists are increasingly occupied with refinement of analytical methods and physicians with specific medical details. With this attention to details within our respective areas there is danger we will lose sight of the continuing need for teamwork which means more than bringing people of different disciplines together in one room.

Each one of us having special competence should recognize what we have to contribute, but we must also know about the contribution from other disciplines in order to practice our own skills more competently in the field. The real need is a mutual understanding of our problems so that we can bring them to the attention of men in the basic sciences and interest them in undertaking necessary research. I would like to have seen more emphasis placed in our discussion on the need for really significant integration of the biological and physical sciences in the study of environmental health problems.

Arthur C. Stern:

We must learn how to translate information gained from industrial exposure into standards for the general population. Unless we learn how to cross this barrier, we will make our job much harder by having to re-do all the good industrial hygiene work already done.

Justus C. Ward:

I would like to thank the Public Health Service for inviting us to participate in the Conference. The presentations have been of interest and should have far-reaching results of practical value.

Robert R. Balmer:

I would like to thank the Public Health Service for inviting industry representatives to this Conference. There is something to be gained by listening to a point of view different from that of our everyday background. I am sure that the discussions presented here do differ from those I hear the other 250 working days of the year. This is helpful to industry and ultimately to the Public Health Service. I appreciate the invitation to be here.

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SUMMARY STATEMENT

MAN IN A COMPLEX ENVIRONMENT

by

Abel Wolman

The entire Conference on "Man Versus Environment" may be described as a reasonably comprehensive look at the complex environment of man. As the speakers looked at this brave new world, it is apparent that the routes chosen were in some instances familiar and orthodox; in others, new casts of players were utilized. The principal problems examined were those of water and wastes, air, food, and occupation.

The purposes of the Conference may be described as threefold: (1) to find out what we do not know, (2) to delineate what we ought to know, and (3) to explore how we may accomplish the second major objective. Essentially, we are faced with a problem in ecology; that is, the influence of the total environment on the behavior of living things. To examine this problem, we must describe a vast amorphous area in which there is an interaction of a variety of functions. Thus, we not only look at man in his environment, but at all organisms.

Out of the deliberations of this Conference comes not a poverty of ideas, but a surfeit of riches in variety and in detail. In that very detail lies a great deal of our problem of analyzing a new kind of objective. The objective is familiar: to go through this forest of suggested rich ideas and emerge with a purposeful program. The search for a new world is an old one, since we are designing and will be designing an environmental Utopia. Sir Thomas More's concept of a Utopia is approximately 440 years old. In some

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respects, it is never attainable. If attained, it would not, necessarily, have all the attractiveness that we might attribute to it. It might have a new set of stresses and strains, if for no other reason than to amuse us.

Components of an Environmental Complex

There are two routes that I might travel in summarizing the presentations in the Conference. I choose the second of these two routes. The first would be to repeat and review all the specific areas of research which have been delineated. I have chosen the second route, which may be more interesting and profitable. This constitutes an attempt to link together environmental complexes which may be common to all the fields described. The common aspects of under-priming not only describe and disclose each of the areas, but actually link them all together. The environmental complex of which we speak has physical, biological and social components. There are multi-causes of common disease and hence the control of disease involves multi-disciplines.

Why does not everyone succumb to amoebic dysentery in those countries where it is endemic? The disease process with which we deal today involves three features instead of one. It involves the host, the agent and, lastly, the environment. We now understand that the tubercle bacillus is not the sole cause of tuberculosis, but one of the causes of tuberculosis. Reduction in the incidence of such a disease was difficult, therefore, because it was a disease of environment, society, and occupation.

The interrelationship between an empirical approach and a basic science approach to the control of the environment is again an area for speculation. Ours is an age of empiricism. We cannot wait, or do not wait, for all the scientific demonstration of cause and effect in every area of activity. Our controls for the future are likely to be based partly on empiricism, partly on scientific proof, and partly on epidemiological cues.

A Summary of Recommendations

With that description of our setting, the recommendations that come out of our discussions appear as follows:

Epidemiology

We must of necessity make promptly a more intensive and profound use of that good old tool, epidemiology, as an analytical discipline. With this we must correlate clinical and experimental observation, in order to narrow the area of ignorance in control of the environment. Epidemiologic inquiry, in its oldest sense should disclose not only the boundaries of ignorance, but also criteria for some empirical action. We have not made complete use of these tools. We need a sharper identification of the cause of disease, than has been the fortunate state of affairs in the case of infectious diseases.

Instrumentation

As additional tools, we must develop methods of study with the newest, as well as the more familiar, instrumentation. We stood still in many areas of inquiry until the microscope was invented. The microscope opened up a new world. The spectroscope, in all fields of biochemistry, is in turn disclosing greater vistas. It has been well stated that "scientific activity has always been conditioned more by available methods for study than by the relative importance of problems."

The intensive challenge of radiation has existed for a matter of only fifteen years. In that fifteen years the development of instrumentation has been tremendous, in order to provide prompt answers to many environmental problems, even while the biological criteria for action were still being sedulously sought.

Criteria

Sound criteria to guide public and private action represent another prerequisite to intelligent programming. These are not tasks for which the Public Health Service is solely responsible. They are tasks in which government, universities, and industry must all participate. We must develop ways of measuring our criteria, and of establishing the levels of those criteria which should lead to action. Radiation exposure and its realistic control, for example, is a new art. Criteria must be developed to guide us in all the new areas so elaborately spelled out at this Conference.

Personnel

We must give consideration to the development of appropriate personnel. Who is to do these things? The functions described are ultimately dependent upon people who will develop ideas; machines will not develop ideas, although we may look now to machines to speed up our tasks.

Again, the development of personnel involves a problem of the integration of disciplines, while, at the same time, we preserve professional identity. Some American universities have tried to do a better job of integration. We face the question of how to bring scientists together, even when their offices are next door to each other. It is the task of the Public Health Service at least to show the way in its own operations. There must, for example, be some relation between cancer and other fields - as one problem of integration. I do not mean we should try to convert our new sanitary engineers into men of omniscience. To solve present and emerging environmental problems, however, our future sanitary engineers must be a part of a team, working with physicists, bio-chemists, chemical engineers, physiologists, and others. Changing our sanitary engineering curriculum to include something in every area does not provide a satisfactory solution. I am a strong adherent of the necessity of maintaining professional identity. Professional identity is more than a label; it is a necessary affiliation of people working in their own or adjacent fields of reasonably well defined character. There is an established field of oceanography. Why should there not be a field of sanitary engineering? The act cannot go forward unless everybody gets into it, without serious loss, however, of professional identity. Given the will, such an integrated approach must emerge.

In the development of personnel, we must find some way in which the generalist, or interdisciplinary worker, can be developed. In this total field of environment where is this spearhead to come from? How do we educate for a generalist? Is it possible to produce such a person? There are generalists in our history, such as Vannevar Bush. Another was Chandler, essentially a chemist, who built up a fine training school at Columbia University and was a leader of public health.

Additional Needs

The word "serendipity" has not been mentioned by earlier speakers. New discoveries and new techniques do not come about only through chance: they depend upon a more important element, the prepared mind of the investigator. Serendipity describes one of the facets for making such discoveries. This is a concept which could well be revived, perhaps by establishing within the Public Health Service a "Department of Serendipity."

We must, of course, list money as one of our needs. It is undoubtedly important, but it is not the major key to the things we are looking for. In this kind of world we cannot do without it. If I were to put money first, however, we would be searching for the wrong single ingredient of our brew.

Tasks of the Public Health Service

Now to define the tasks of the Public Health Service, as my personal understanding of what this Conference proposes:

1. We ask of the Public Health Service a working concept of environmental hygiene. This is simple in terminology, but very broad as to base. It must represent a collateral relationship in functions of many disciplines and, equally important, a wholehearted sympathy with such a concept.

2. We look to the Service for leadership in the cross fertilization of disciplines. It has the opportunity to bring people together in daily work as well as in intermittent conferences.

3. In the area of environmental hygiene, the Service can design a workshop for the engineer, biologist, physicist, and social scientist where they work jointly, with the corridors so constructed that people must bump into each other.

4. The Service should make maximum use of communications to insure that various disciplines related to the environment think jointly with the increasing aid of mechanical devices of automation.

5. These functions lead to another task, namely, to provide the aids for selection of objectives in the field of environmental control.

There are different levels of priority, and the Service must do its best to establish what these priorities are on a moving chronological scale, what things come first in environmental control?

6. There must be a realistic appraisal of semantic slogans versus supportable guides for scientific and technological action. Reflections of popular interest and desire are not necessarily warranted as guides for programs. People working in this field have a responsibility for separating what makes sense and what does not make sense in a realistic effort.

May I close by noting that ours is an obviously complex task. Dr. William H. Welch, working in the 1900's, who was such a generalist as I have cited, must have thought his world complex in terms of need for the analysis of water. Today, I have the same optimism. In "The Education of Henry Adams" it was suggested that the necessity for improved education increases proportionately with the coal output. Our industrialization has brought progress and problems which must be balanced with education. As Adams noted: "For a thousand years man has kept in step with his changing needs; he probably will continue to do so, only now he will have to jump."

* * *

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